DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
Washington, DC 20314-1000

CEMP-ET

ETL 1110-3-438

Technical Letter
No. 1110-3-438

15 September 1993

Engineering and Design
INDOOR RADON PREVENTION AND MITIGATION

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Report Documentation Page

Report Date	Report Type	Dates Covered (from... to)
15 Sep 1993	N/A	-

Title and Subtitle Engineering and Design: Indoor Radon Prevention and Mitigation	**Contract Number**
	Grant Number
	Program Element Number
Author(s)	**Project Number**
	Task Number
	Work Unit Number
Performing Organization Name(s) and Address(es) Department of the Army U.S. Army Corps of Engineers Washington, DC 20314-1000	**Performing Organization Report Number**
Sponsoring/Monitoring Agency Name(s) and Address(es)	**Sponsor/Monitor's Acronym(s)**
	Sponsor/Monitor's Report Number(s)
Distribution/Availability Statement Approved for public release, distribution unlimited	
Supplementary Notes	
Abstract	
Subject Terms	
Report Classification unclassified	**Classification of this page** unclassified
Classification of Abstract unclassified	**Limitation of Abstract** UU
Number of Pages 38	

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INDOOR RADON PREVENTION AND MITIGATION

1. Purpose. This letter provides advance criteria to be used for prevention and mitigation in indoor radon in newly constructed buildings.

2. Applicability. This letter applies to HQUSACE elements, major subordinate commands, districts, laboratories, and field operating activities (FOA) having military design and construction responsibility.

3. Action to be Taken. Pending publication of permanent media guidance, the criteria provided in Appendix A will be used as interim guidance to prevent and mitigate indoor radon in all newly constructed and substantially altered Army facilities. The design requirements set forth in this letter are mandatory.

4. Implementation. This letter will have routine application as defined in paragraph 6c, ER 1110-345-100.

FOR THE DIRECTOR OF MILITARY PROGRAMS:

1 APPENDIX
APP A - Indoor Radon
Prevention and Mitigation

Frank Alicia
RICHARD C. ARMSTRONG, P.E.
Chief, Engineering Division
Directorate of Military Programs

This ETL Supersedes ETL 1110-3—427, 15 June 1990

APPENDIX A

US Army Corps
of Engineers

INDOOR RADON PREVENTION AND MITIGATION

INDOOR RANDON PREVENTION AND MITIGATION

TABLE OF CONTENTS

INDOOR RADON PREVENTION AND MITIGATION

1. PURPOSE: This letter establishes design criteria for all U.S. Army facilities to eliminate health risks due to indoor radon.

2. SCOPE: The design standards established herein are applicable to all newly constructed and substantially altered Army facilities both inside and outside the Continental United States.

3. REFERENCES:

a. DA Publication.

AR 200-1, Chapter 11, Army Radon Reduction Program.

b. U.S. Environmental Protection Agency (EPA) Publications.

(1) EPA 520/11-87-20, Radon Reference Manual.
(2) EPA 600/8-88-087, Radon-Resistant Residential New Construction.
(3) EPA 625/5-87/019, Radon Reduction Techniques for Detached Houses.
(4) EPA 625/5-88/024, Application of Radon Reduction Methods.

(Most of the research work and publications by EPA have concentrated on single family, detached dwellings. Military facilities are generally larger and of different construction methods than single family residences. The design criteria and details contained in this document are selectively adapted from the EPA data and recommendations.)

4. PROPERTIES OF RADON: Radon is a naturally occurring, chemically inert and water soluble radioactive gas that is undetectable by human senses. It is formed by the radioactive decay of thorium and uranium. These source elements are found in low, but varying; concentrations in soils and rocks. Radon, being a gas, escapes from the ground following paths of least resistance such as through small fissures, gravel, sand, and other porous soils. Normal subsoil investigations do not locate these radon paths with sufficient detail and accuracy to reliably predict points where radon emerges from the earth or probable levels of concentration. Radon-220, derived from thorium, has a half-life of 55 seconds giving it limited time to enter buildings before it decays to a nongaseous element. Radon-222, derived from uranium and having a halflife of 3.8 days, is the primary source of indoor radon. Refer to EPA 520/1-87-20, Radon Reference Manual for more detailed information.

5. OTHER RISKS: Health risks associated with radon are from its decay products, not the radon gas. Radon-222 decays in several

steps to form non-gaseous radioactive isotopes with short half-lives. Four of these successive decay products have half lives less than 30 minutes. These isotopes are chemically reactive and attach to building surfaces and airborne dust particles. Both attached and unattached decay products can be inhaled and attach to lung tissue. Further radioactive decay of these isotopes releases alpha particles that damage lung tissue and leads to lung cancer.

EPA recommends the removal of radon gas rather than removal of decay products with high efficiency air filters or air cleaning devices. For more information on the disadvantages of air cleaning as the primary method for radon control, refer to EPA 625/5-87/019, Radon Reduction Techniques for Detached Houses, Paragraph E.2.5. and Section 7.

6. PRIORITY OF FACILITY TYPES: Priorities for designing various types of military facilities to reduce indoor radon are based upon the priorities contained in AR 200-1, Chapter 11.

a. Priority 1: Day care centers, hospitals, schools, living quarters including barracks, unaccompanied personnel housing (officers and enlisted) and family housing, and routinely occupied spaces below grade.

b. Priority 2: Offices, work areas, and other facilities having 24-hour operations.

c. Priority 3: All other routinely occupied structures including morale, welfare and recreational facilities.

d. Priority 4: All intermittently occupied structures that are used by any military or civilian employee whose total work time in those buildings equals or exceeds 80 hours per year.

e. Structures occupied less than 80 hours per year by any employee do not require radon preventive measures.

7. INDOOR RADON CONCENTRATION AND ACTION LEVELS: Radon is measured in picocurries per liter (pCi/l) of air. EPA studies have assigned relative health risks for various concentration levels of indoor radon based upon periods of exposure; concentration levels below 4 pCi/l are negligible.

The action levels given below conform to AR 200-1, Chapter 11:

a. Negligible : 0 to 4 pCi/l.

b. low : 4 to 8 pCi/l.

c. Moderate : 8 to 20 pCi/l.

d. High : 20 to 200 pci/l.

e. Very High Greater than 200 pCi/l.

8. DETERMINATION OF RADON POTENT: AR 200-1, Chapter 11 establishes a program for measuring indoor radon in existing buildings on Army installations and buildings owned or leased by the Army (CONUS and OCONUS). The measurements were to be completed by the fourth quarter of FY 91. Each installation is required to maintain records of the radon measurements and to make annual reports on all radon mitigation activities. The pre-mitigation measurements in existing buildings will be the basis for potential radon levels for new facilities.

Design criteria will be based upon the highest radon measurements in existing buildings in close proximity to the new facility. Where the new facility is in a remote location, the highest measurements on the installation will determine the design criteria. In cases where existing radon data are not available, soil-based radon and radium measurement may provide useful information in evaluating radon potentials. Procedures for using soil gas measurements to estimate radon potentials are still evolving, contact EPA for the most up-to-date guidance

9. DESIGN REQUIREMENTS:

a. New Construction. Design requirements consist of passive barriers to seal radon entry routes and active sub-slab suction systems to remove radon gas from the soil under floor slabs and around below grade walls. The objective of both passive and active design strategies is to prevent radon entry to interior spaces. Specific design requirements, based upon facility priority and potential radon concentration, are listed in Table 1 by letter codes. The letter codes are described below and indicated on the details in Paragraph 12.

(1) Passive Barriers, Letter Code A. Passive barriers are required for facility priorities 1 through 4 and for all potential radon concentration levels. Passive barriers include 6 mil polyethylene sheet in crawl spaces and under floor slabs on grade, capillary water barrier below floor slabs on grade, dampproofing or waterproofing and protection board on below grade walls, sealants in all joints in floor slabs, below grade walls and around all pipe and conduit penetrations. Provide solid courses in hollow masonry walls to prevent gas passage through the internal voids. Joint sealants will be selected and installed according to TM 5-805-6 and CEGS 07920. Polyethylene sheets will be lapped 12 inches and sealed with adhesives or pressure sensitive tape and sealed at foundation walls with mastic. Capillary water barrier will be according to CEGS 02221, dated March 1991, except the last sentence in the Note under Paragraph 3.16 is not applicable.

(2) Sub-slab Suction Systems, Letter Codes B, C, and D. Sub-slab suction systems consist of 4 inch diameter perforated PVC pipe laid in the capillary water barrier below floor slabs which are used

to create negative pressure fields under the floor. Provide a suction stack connection, using non-perforated PVC pipe, stubbed through the floor slab and capped. The suction stack should be near the middle of the under slab pipe run and be located where it can be extended through the building roof with minimum changes of direction. Requirements for letter codes B, C, and D are identical except for the spacing for under slab pipe runs. In structures with basements or other below grade spaces, connect the sub-slab piping to the foundation drainage system so that the negative pressure field is extended to the earth side of below grade walls. Where the foundation drainage has gravity outfall, provide an interior suction stack and a water trap as shown in Details 31 and 32. Where foundation drains discharge to a sump, seal the sump cover and provide a suction stack connection to the sump as shown in Detail 33; large buildings will require additional suction stacks remote from the sump. Building sites with seasonally high ground water may require a high water sensor at the suction stack connection to shut off the suction fan. Radon gas is water soluble. It is reasonable to assume that a properly designed sub-soil drainage system will remove radon from sites with severe ground water problems.

(3) Passive Suction Stack, Letter Code E. Extend non-perforated PVC pipe suction stack through the roof with as few changes in direction as possible. Passive stacks are more effective in colder climates and during winter months than during warm weather. During warm weather they will be most effective in naturally ventilated, non air conditioned buildings.

(4) Active Suction Stack, Letter Code F. Extend the suction stack as described above for the passive stack and install an exhaust fan near the stack discharge. preferred location for the exhaust fan is above the roof. Condensation of moisture in soil gases will be minimized if the fan is located in a heated space, however, any air leakage that may occur at the fan discharge connection will blow concentrated radon into the building. Any air leakage at the fan intake connection will reduce the suction in the stack.

(5) Design of Sub-Slab Suction System. Pipe sizing for the suction system should be designed similar to any exhaust system utilizing round duct. The under slab perforated pipe should be no larger than 4 inch diameter. In very large structures, do not increase the pipe diameter in order to increase the length of pipe runs, this may reduce uniformity in the pressure field. The quantity of air flow in a sub-slab suction system is effected by a number of variables. The most significant are porosity of the soil, permeability of the capillary water barrier, and air leakage from the building into the soil. In most locations, the air flow per 1,000 sq. ft. of slab area will be 20 cfm or less. Multiple under slab pipe runs may be cross connected below the floor using non-perforated pipe of sufficient diameter to maintain uniform pressure in all pipe runs. Multiple stacks may be connected to a common exhaust fan. Pipes for stacks and any manifolds will be sized

according to air flow and pressure losses due to pipe length and number of turns.

(6) Fan Selection. The fan selected will have cfm and horse power ratings adequate to maintain 1 inch wc static pressure at the slab penetration under constant operation. This will be mounted directly in or to the vertical riser with air tight connections and will be of such design that condensation of soil gas moisture will drain either back down the stack or onto the roof. Fans may be an in-line configuration and installed in the stack or a standard curb mounted exhaust fan.

(7) Naturally Ventilated Buildings. Naturally ventilated buildings that are neither heated or cooled by mechanical systems and are in any of the facility priorities 1 through 4 will be designed to include passive barriers (letter code A) only.

		POTENTIAL	RADON CONCENTRATION		
PRIORITIES FOR FACILITY TYPES	NEGLIGIBLE 0 TO 4pCi/1	LOW 4 TO8 pCi/l	MODERATE 8 TO 20 pCi/l	HIGH 20 TO 200 pCi/l	VERY HIGH Over 200 pCi/l
1	A	A,B	A,C	A,D,E	A,D,F
2	A	A,B	A,B	A,D,E	A,D,F
3	A	A,B	A,B	A,C	A,D,E
4	A	A	A	A,B	A,C

TABLE 1. DESIGN REQUIRMENTS FOR RADON PREVENTION

b. Existing Buildings. Radon mitigation requirements incorporated into the design of building alterations will be based upon the facility priority and actual radon measurements in the building. The design requirements in Table 1 will be evaluated according to life cycle cost/benefit analysis and engineering judgment. For example, removal of slab-on-grade floors to install a sub-slab suction system may not be cost effective when compared to the differential in equipment and operating costs to increase interior air pressure or the outside-air exchange rate.

10. POST CONSTRUCTION RADON MEASURE:

a. After completion of construction, indoor radon measurements will be made with all HVAC systems operating on normal cycles. Radon detectors and laboratory analytical services will be obtained through U.S. Army Center for Pubilc Works. Ft. Belvoir. Virginia 22060-5516.

b. The severity of potential. indoor radon concentration cannot be accurately predicted. The time duration for post construction radon measurements and the extent of mitigation work that may be

required is not quantifiable for inclusion in construction contracts. Therefore, the installation or user agency will be responsible for post construction radon measurement and mitigation.

11. POST CONSTRUCTION RADON MITIGATION: When post construction radon measurements are greater than 4 pci/l, mitigation systems designed into the facility will be activated incrementally until the radon level is reduced to less than 4 pci/l. The incremental steps are as follows:

a. Activate sub-slab suction systems or power ventilate crawl spaces.

(1) Install passive vent stack(s) to sub-slab systems for low and moderate radon levels. If subsequent radon measurements are greater than 4 pci/ 1, then install exhaust fans for active vent stack.

(2) Install active vent stack(s) with exhaust fans for high and very high radon levels.

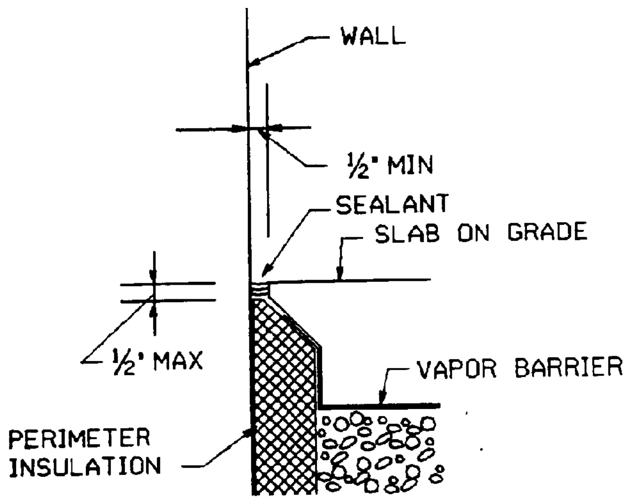
b. Increase interior positive air pressure.

c. Increase the outside-air exchange rate.

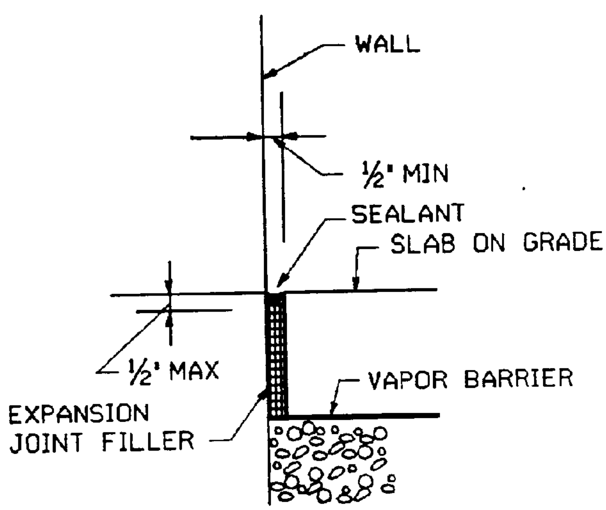
12. DESIGN DETAILS:

a. The following design details are generic in nature to depict a variety of typical conditions that are adaptable to specific building designs. Some details shown may not be applicable to every building; unique conditions are not included. Each detail and/or portions thereof are identified with letter codes that relate to Table 1. Additional design guidance may be found in the EPA publications listed in Paragraphs 3.a.(2), (3), and (4).

b. Reinforcing for concrete and masonry construction shall be provided according to specific design requirements and is not indicated in the following details. Minimum reinforcement to control shrinkage cracks in concrete slabs on grade will be 6x6-wl.4xwl.4 welded wire fabric.

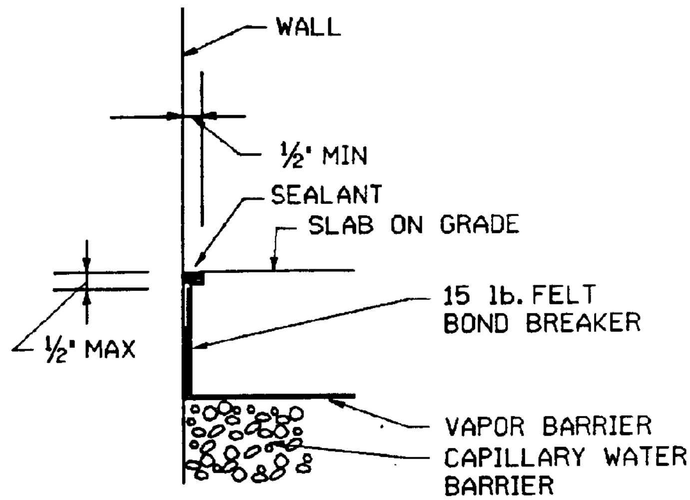


JOINT DETAIL 1
SLAB EDGE WITH
PERIMETER INSULATION
CODE A

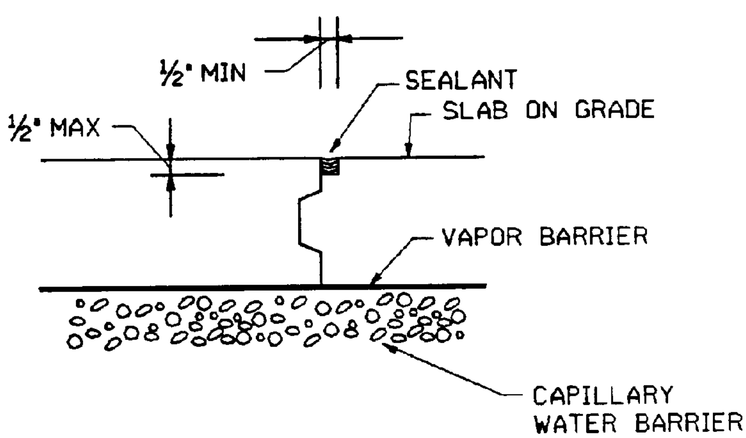


JOINT DETAIL 2
SLAB EDGE WITH EXPANSION
JOINT
CODE A

FLOOR JOINTS
SLAB ON GRADE



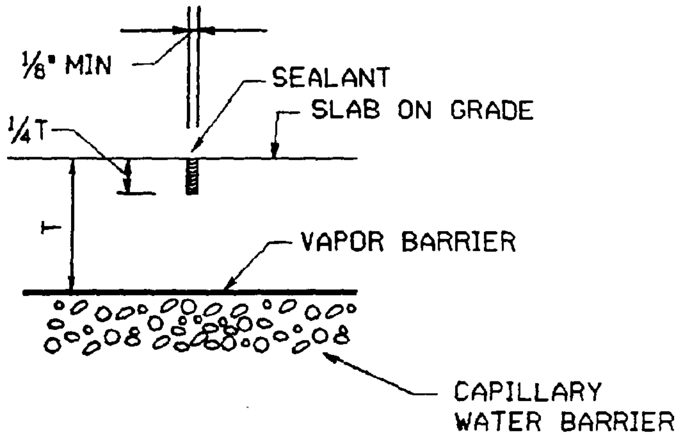
JOINT DETAIL 3
SLAB EDGE WITH BOND BARRIER
CODE A



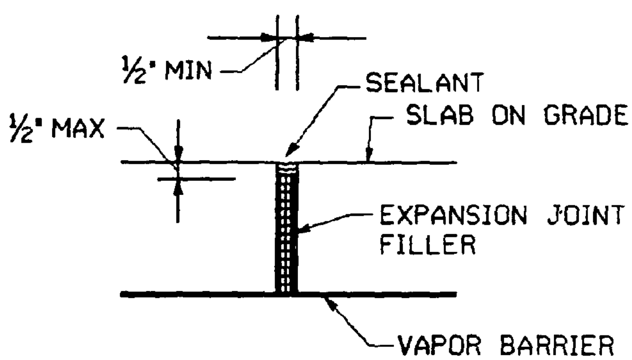
JOINT DETAIL 4
CONSTRUCTION JOINT
CODE A

8

FLOOR JOINTS
SLAB ON GRADE



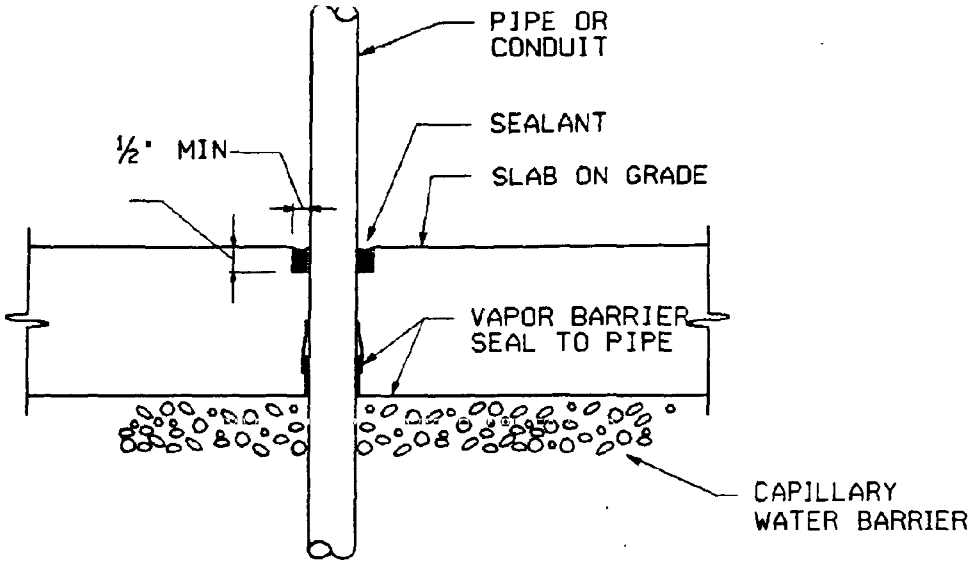
JOINT DETAIL (5)
CONTROL JOINT
CODE A



JOINT DETAIL (6)
EXPANSION JOINT
CODE A

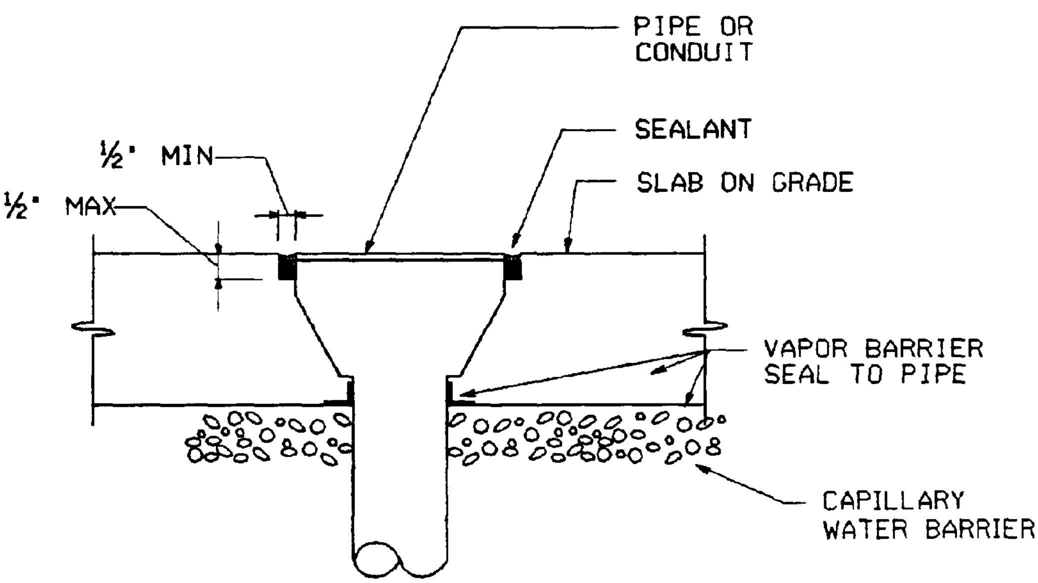
9

FLOOR JOINTS
SLAB ON GRADE



DETAIL 7

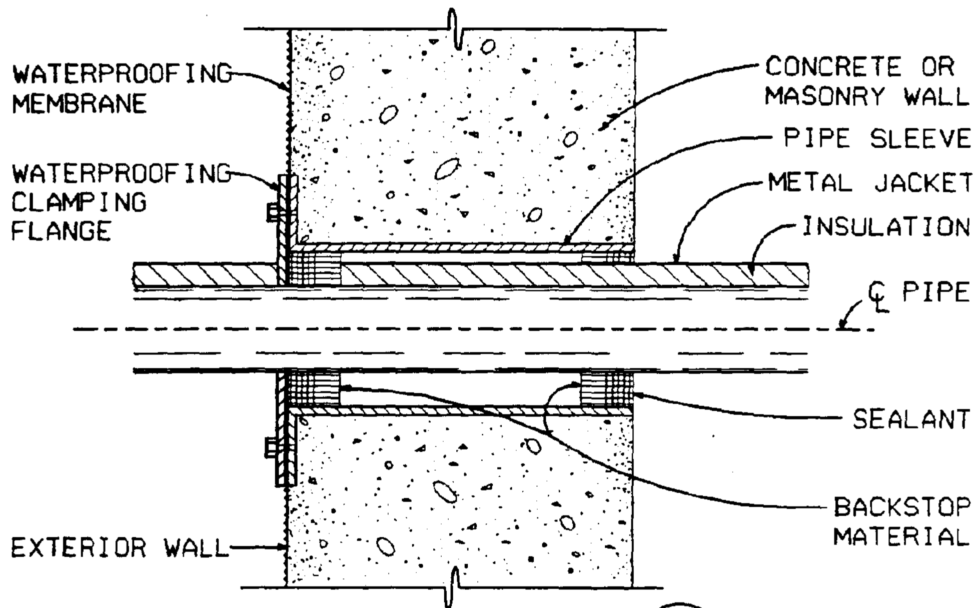
PIPE OR CONDUIT
PENETRATION
CODE A



DETAIL 8

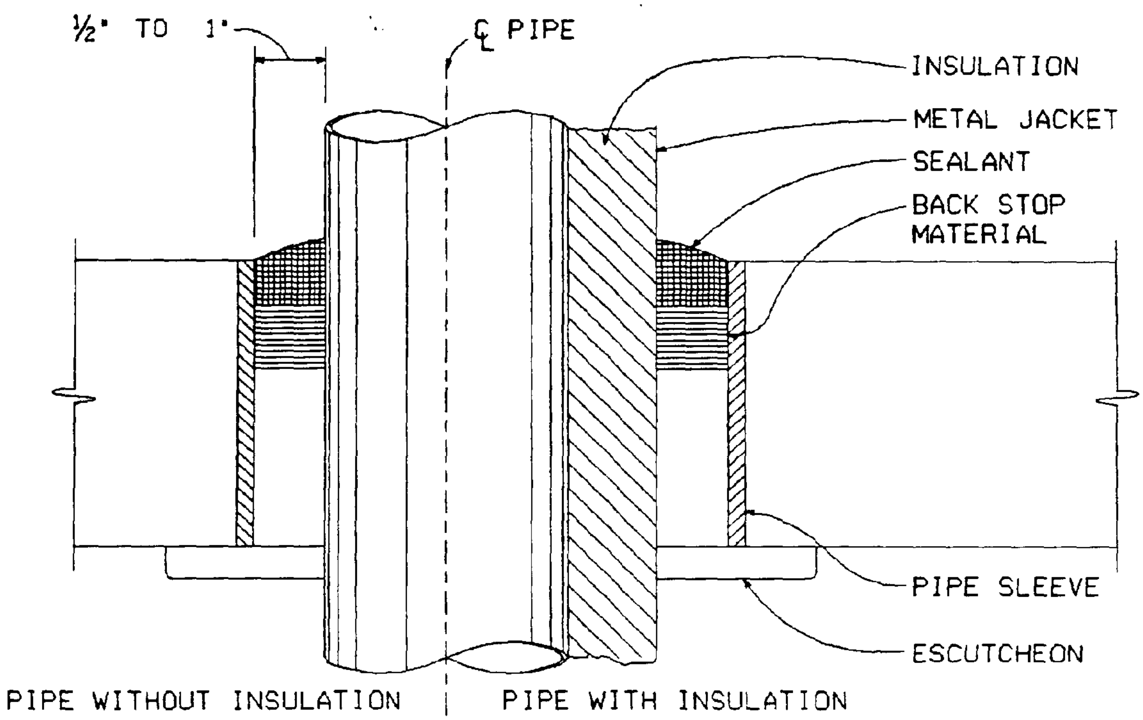
AT FLOOR FIXTURES

CODE A



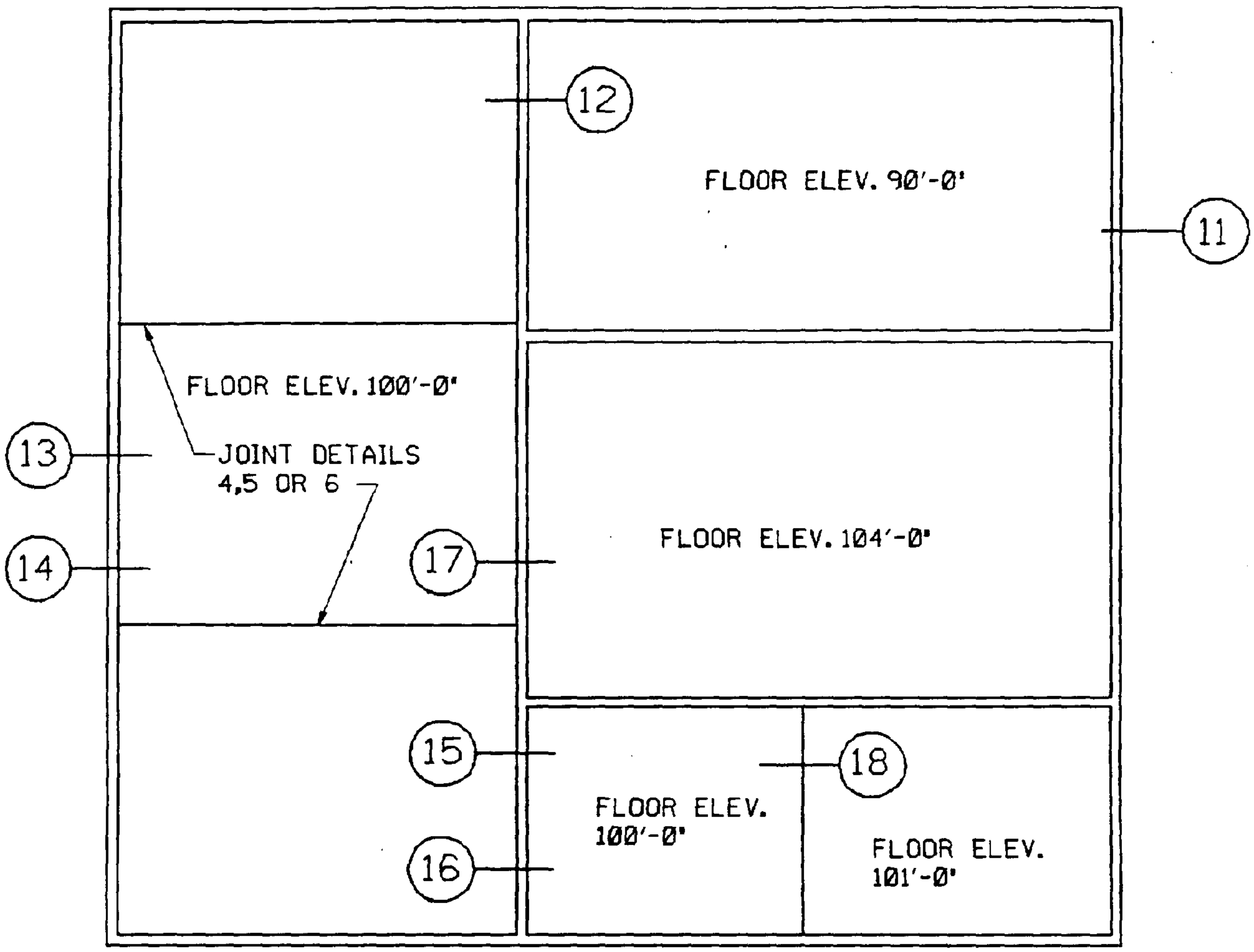
DETAIL 9
PIPE OR CONDUIT THROUGH BELOW GRADE WALL

CODE A



JOINT DETAIL 10
PIPE OR CONDUIT THROUGH FLOOR OVER CRAWL SPACE

CODE A



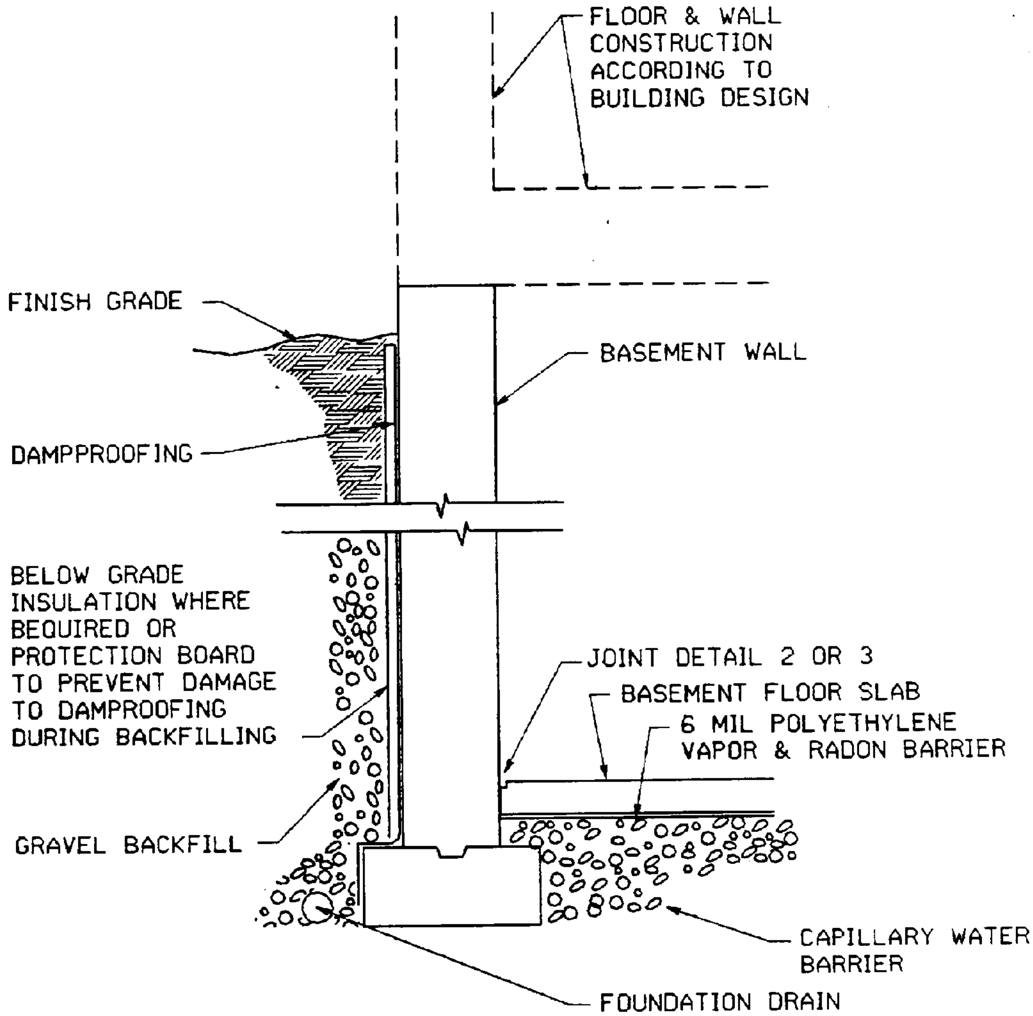
FOUNDATION & SLAB PLAN

NO SCALE

PLAN AND FLOOR ELEVATIONS ILLUSTRATE TYPICAL LOCATIONS WHERE RADON BARRIER DETAILS ARE REQUIRED

12

CONCRETE FOUNDATION



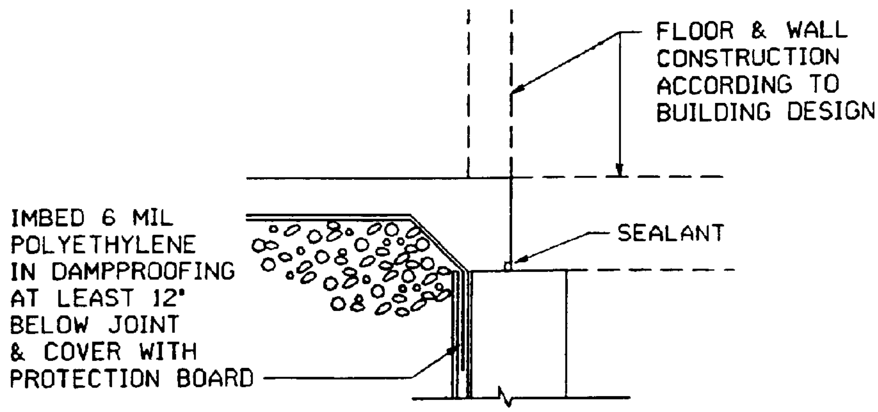
DETAIL 11

EXTERIOR BASEMENT WALL

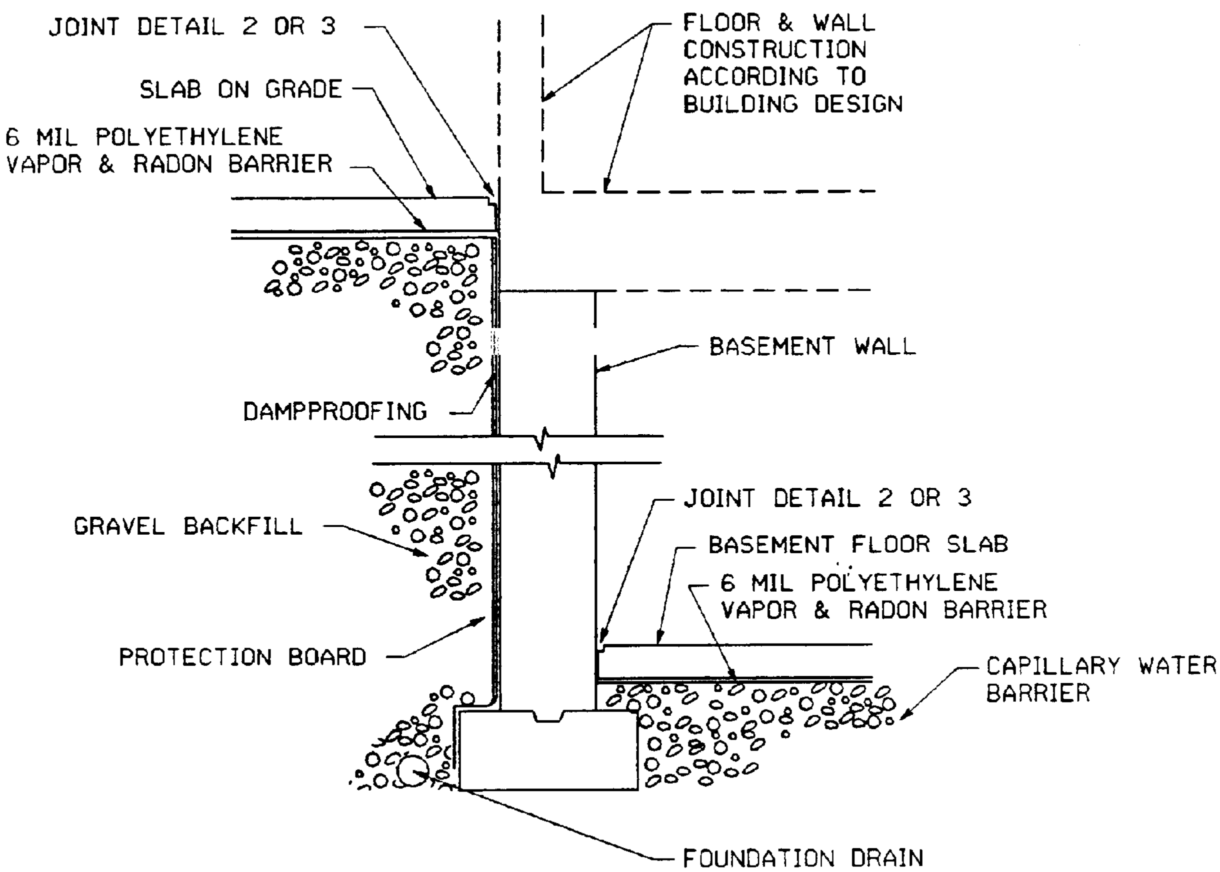
CODE A

13

CONCRETE FOUNDATION



ALTERNATE FIRST FLOOR DETAIL

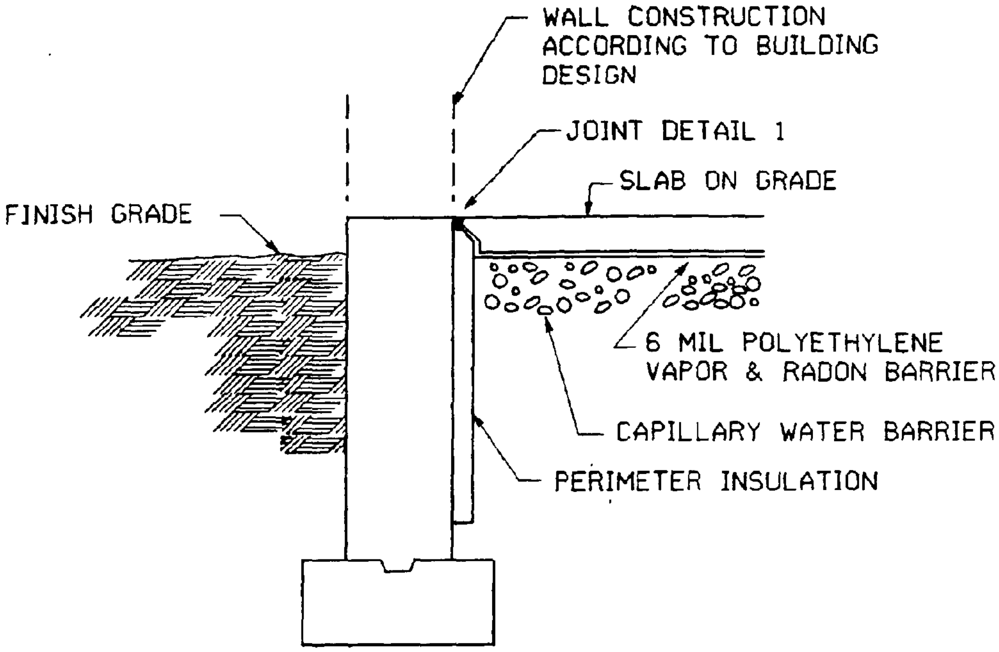


DETAIL 12

EXTERIOR BASEMENT WALL

CODE A

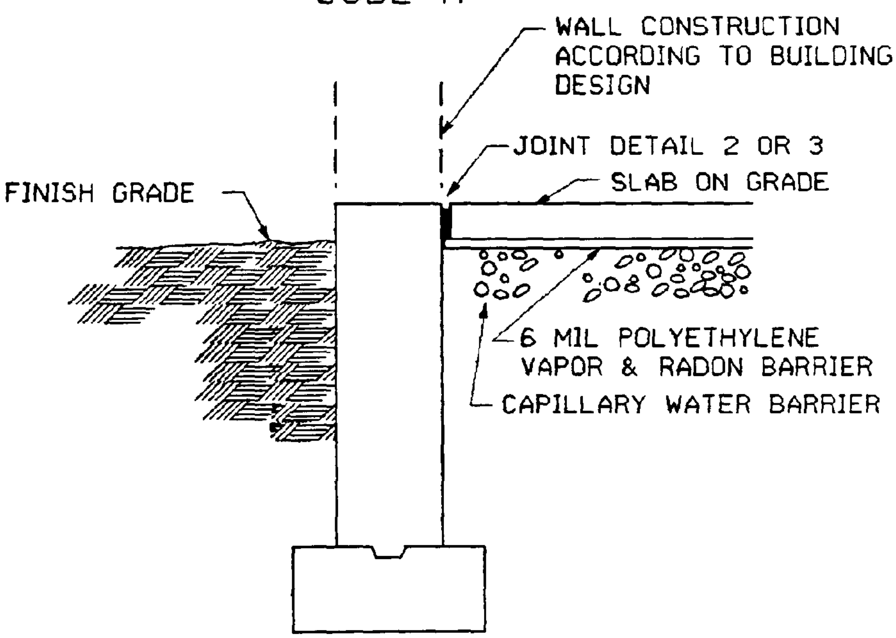
CONCRETE FOUNDATION



DETAIL 13

EXTERIOR WALL WITH PERIMETER INSULATION

CODE A

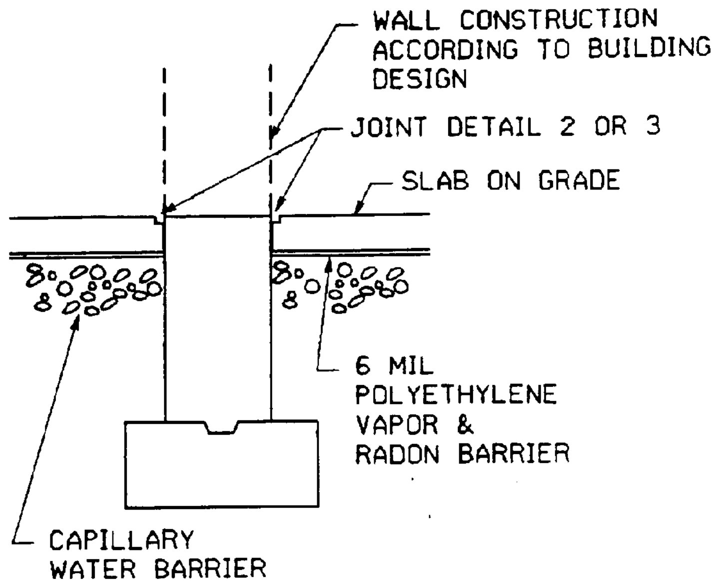


DETAIL 14

EXTERIOR WALL UNINSULATED

CODE A

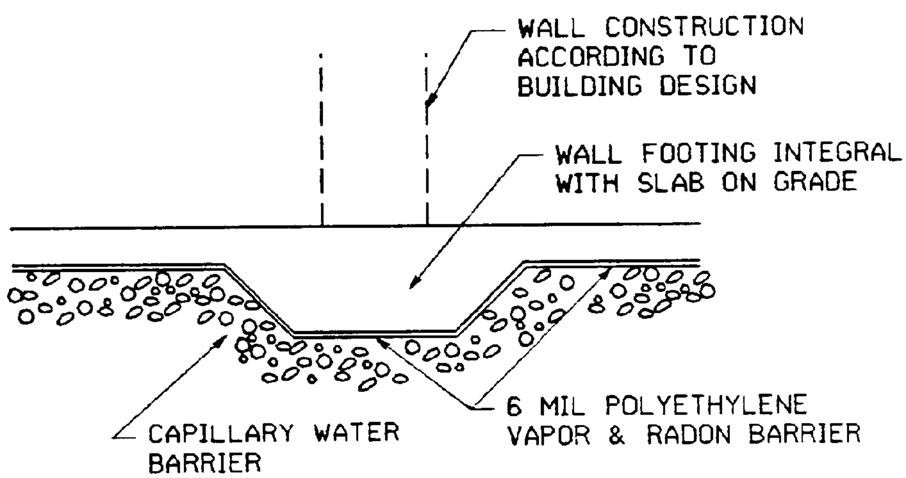
15



DETAIL 15

INTERIOR WALL

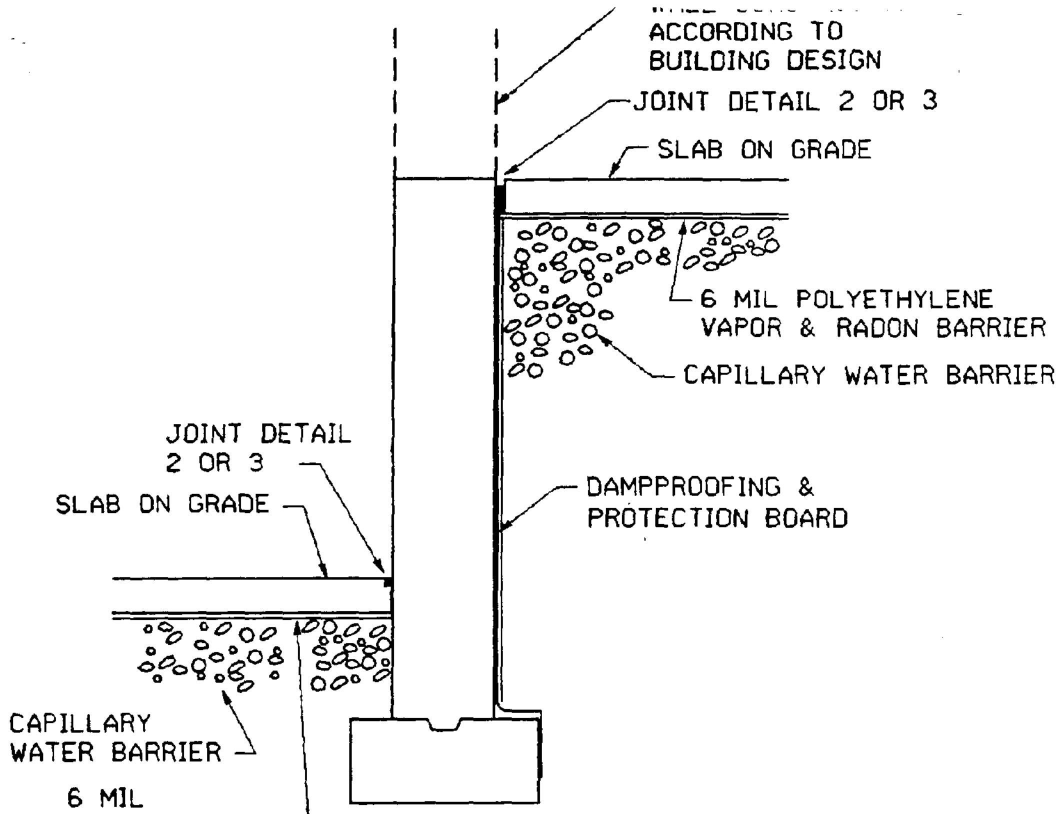
CODE A



DETAIL 16

INTERIOR WALL

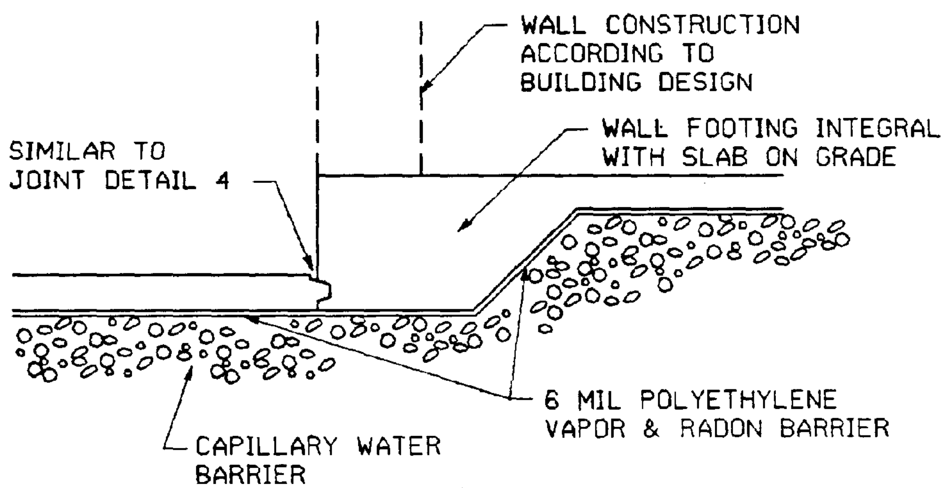
CODE A



DETAIL 17

INTERIOR WALL WALL
CHANGE IN FLOOR LEVEL

CODE A



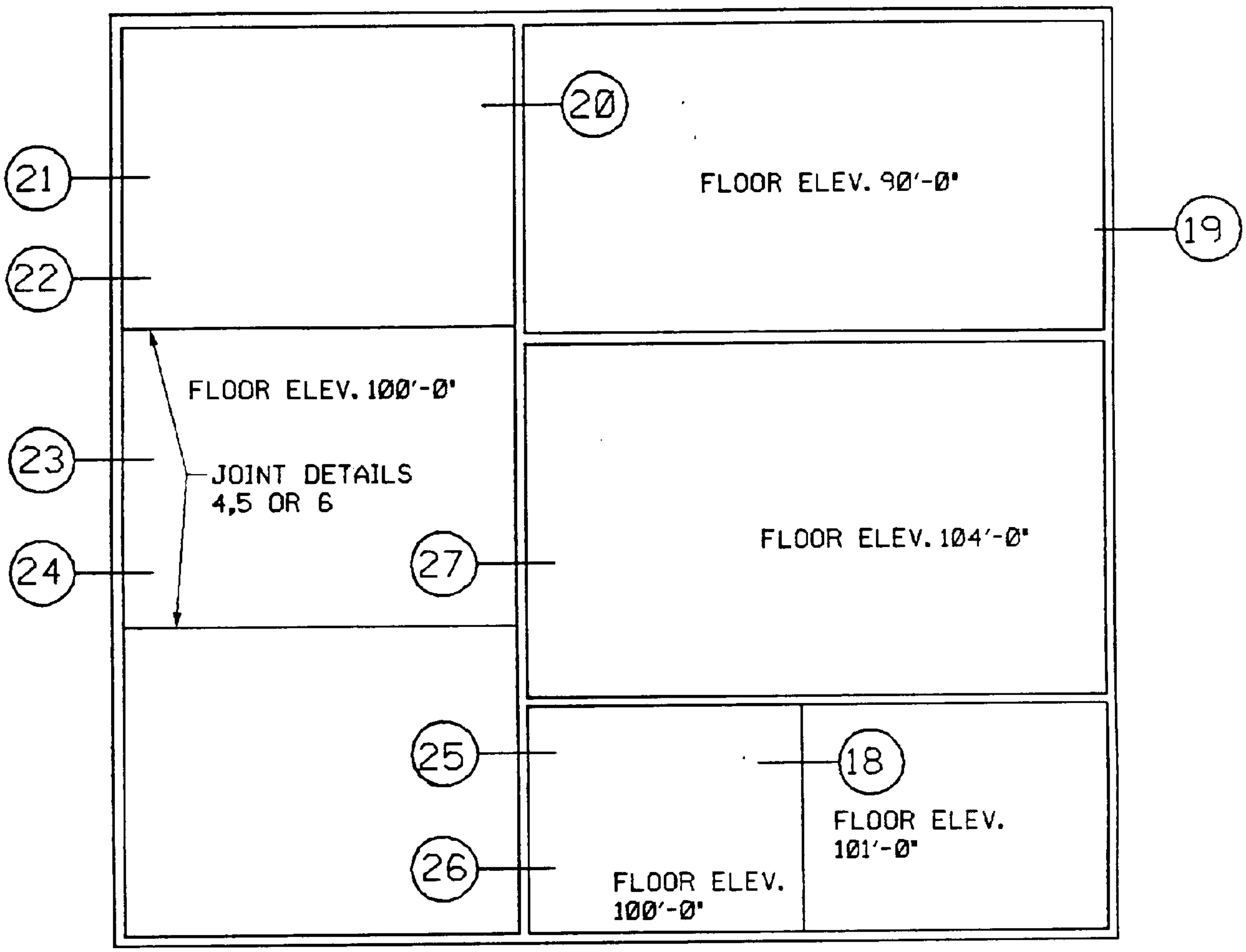
DETAIL 18

CHANGE IN FLOOR LEVEL
(EQUIPMENT PAD SIMILAR)

CODE A

17

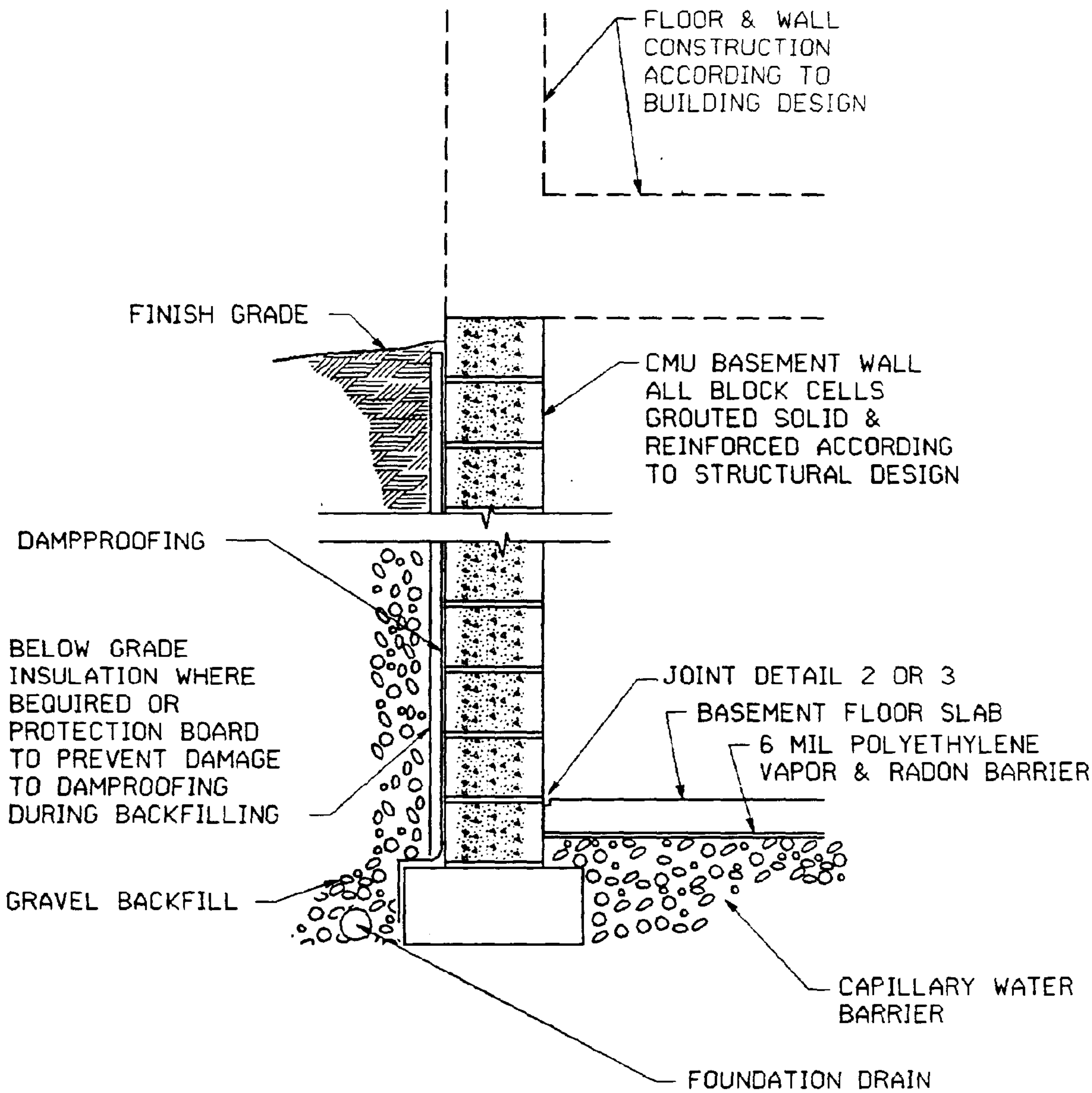
CONCRETE FOUNDATION



FOUNDATION & SLAB PLAN

NO SCALE

PLAN AND FLOOR ILLUSTRATE TYPICAL LOCATIONS WHERE RADON BARRIER DETAILS ARE REQUIRED



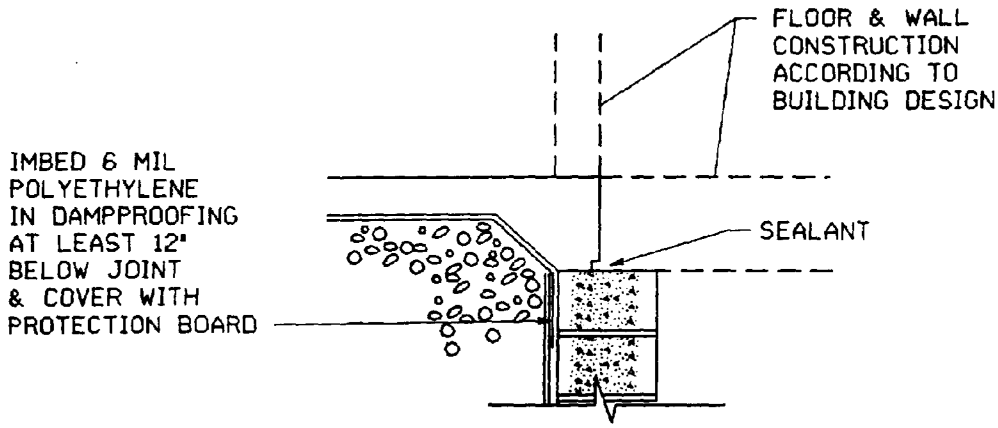
DETAIL 19

EXTERIOR BASEMENT WALL

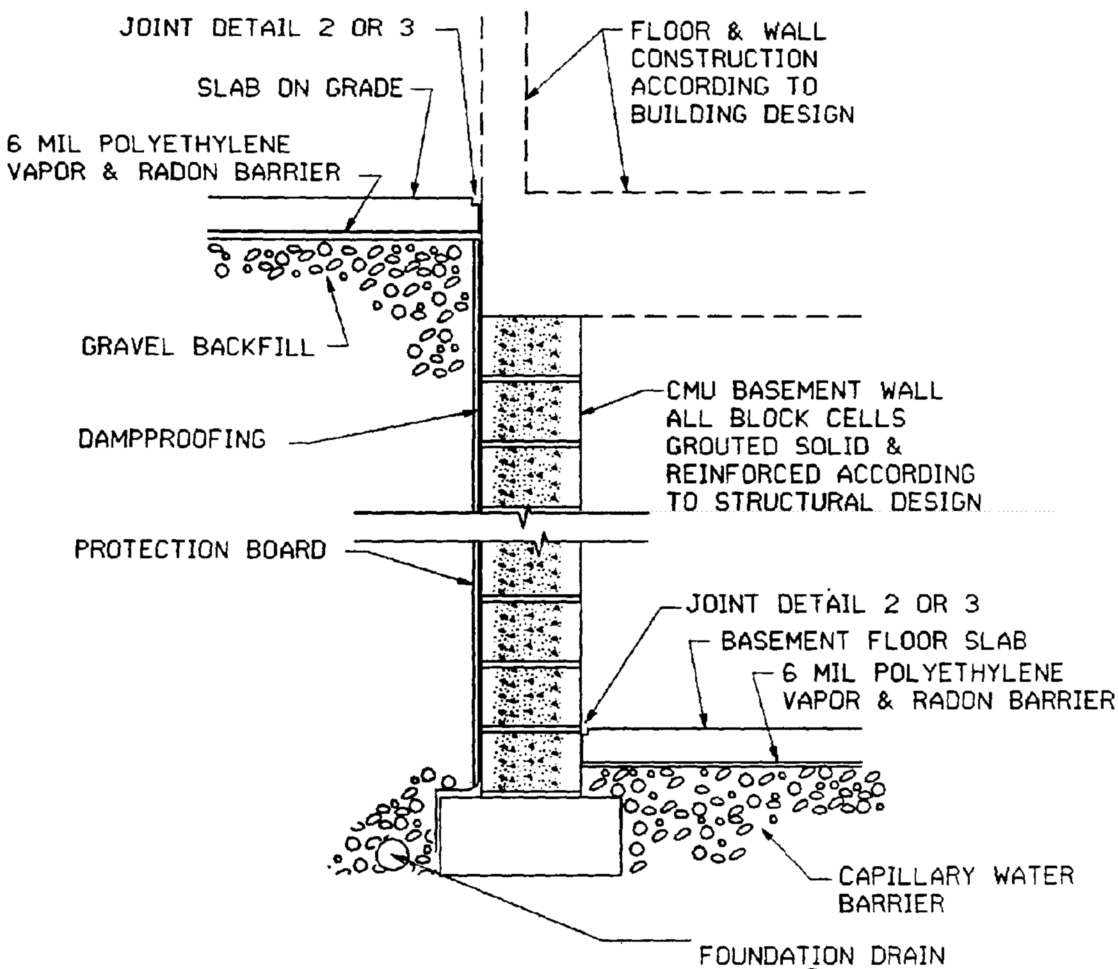
CODE A

19

MASONRY FOUNDATION



ALTERNATE FIRST FLOOR DETAIL

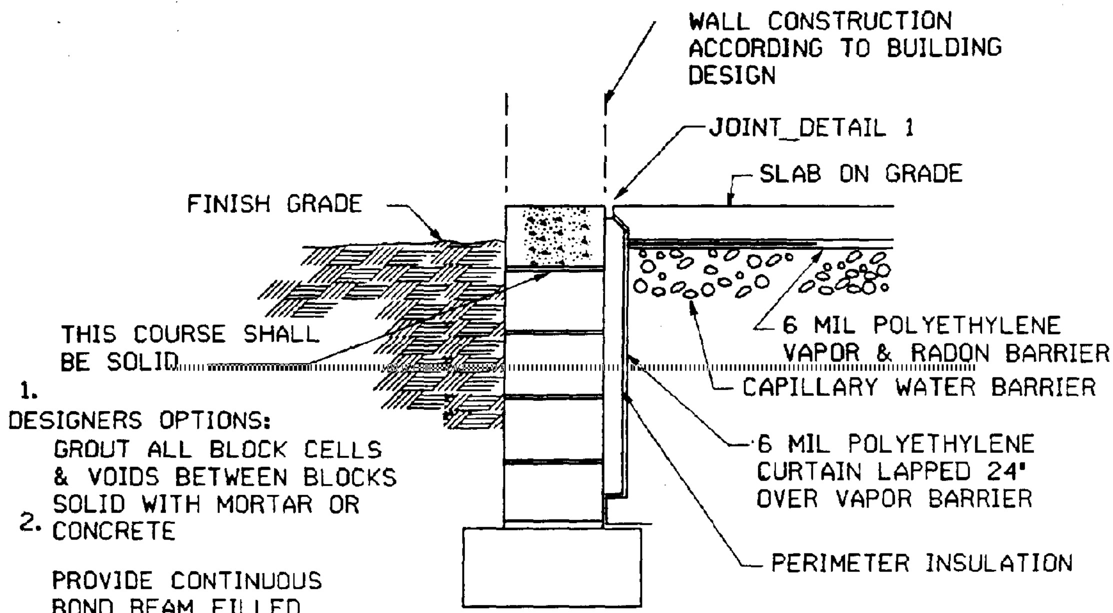


DETAIL 20
INTERIOR BASEMENT WALL
JOINING SLAB ON GRADE

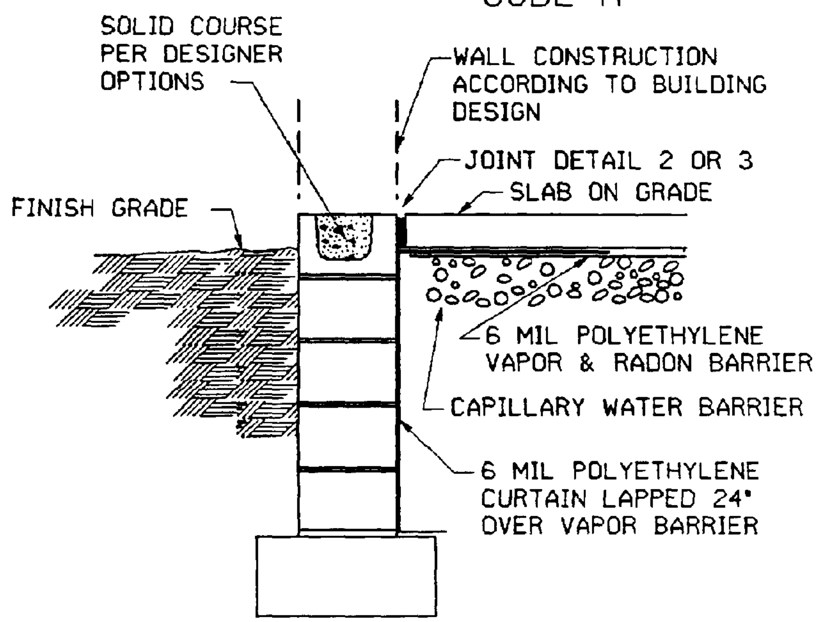
CODE A

20

MASONRY FOUNDATION



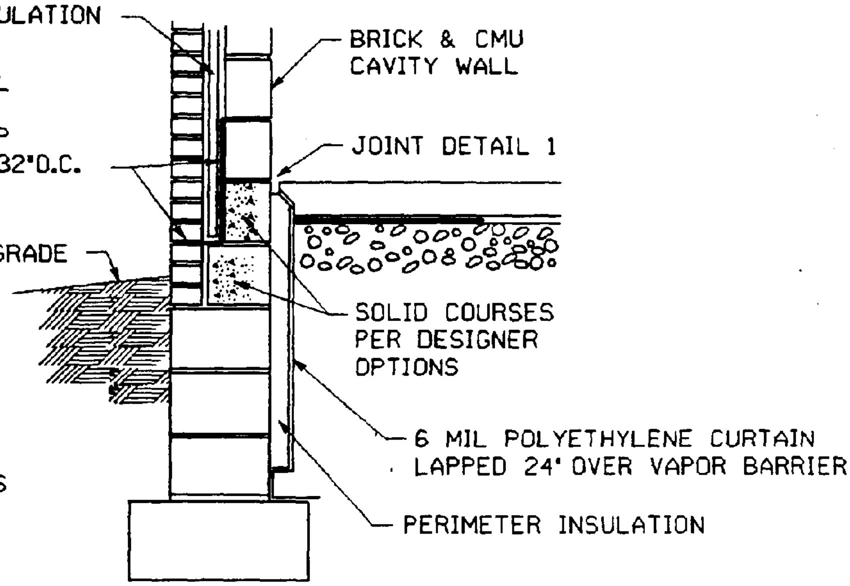
DETAIL 21
EXTERIOR WALL WITH PERIMETER INSULATION
CODE A



DETAIL 22
EXTERIOR WALL UNINSULATED
CODE A

21

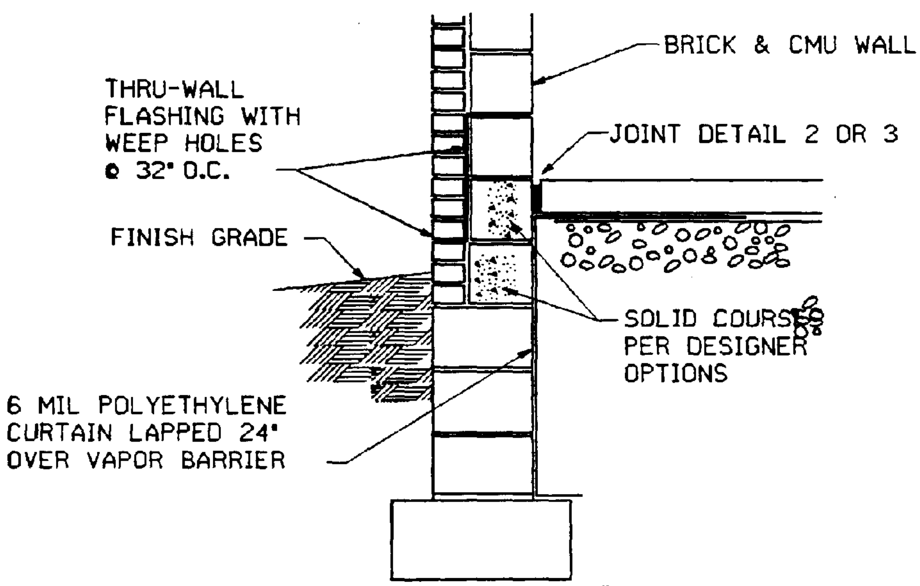
MASONRY FOUNDATION



DESIGNERS OPTIONS:
1. GROUT ALL BLOCK CELLS & VOIDS BETWEEN BLOCKS SOLID WITH MORTAR OR CONCRETE
2. PROVIDE CONTINUOUS BOND BEAM FILLED WITH CONCRETE
3. SOLID CMU WITH ALL HEAD JOINTS COMPLETELY FILLED

DETAIL 23

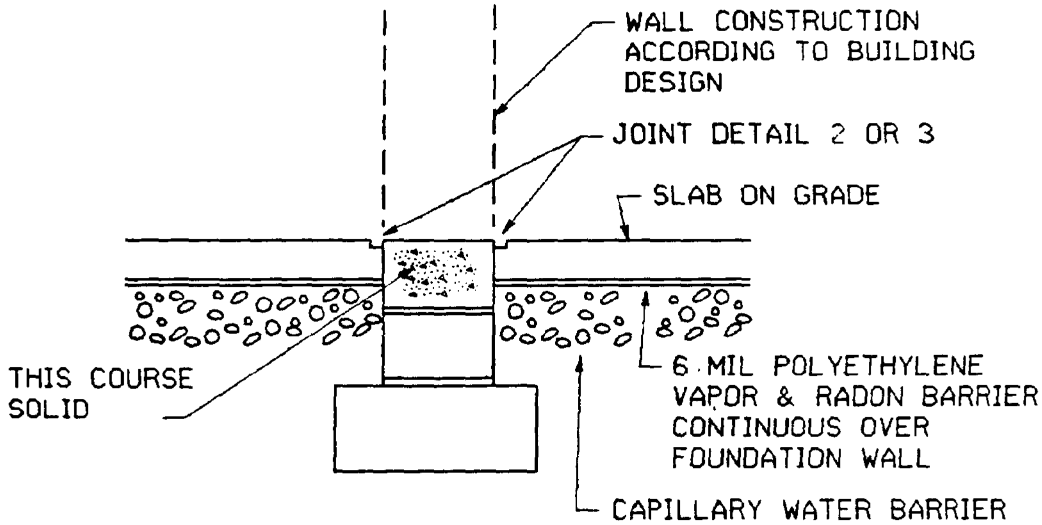
EXTERIOR MASONRY CAVITY WALL INSULATED
CODE A



DETAIL 24

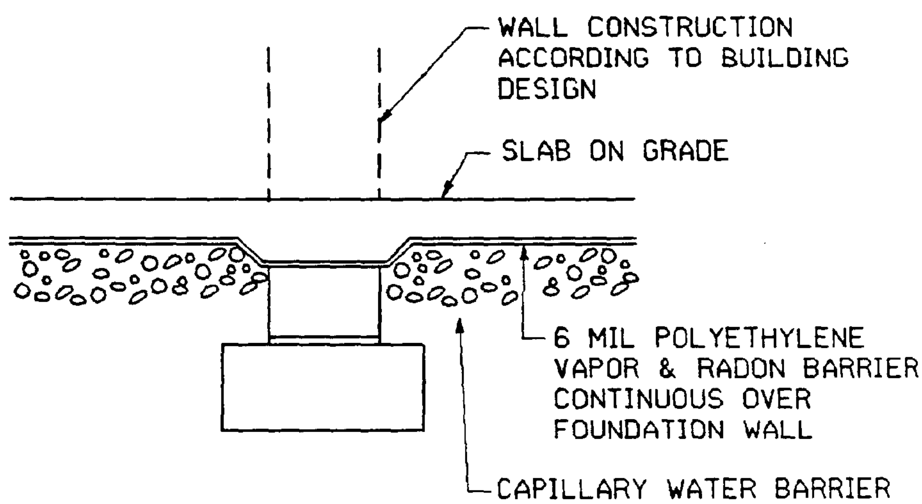
EXTERIOR MASONRY CAVITY WALL UNINSULATED
CODE A

22 MASONRY FOUNDATION



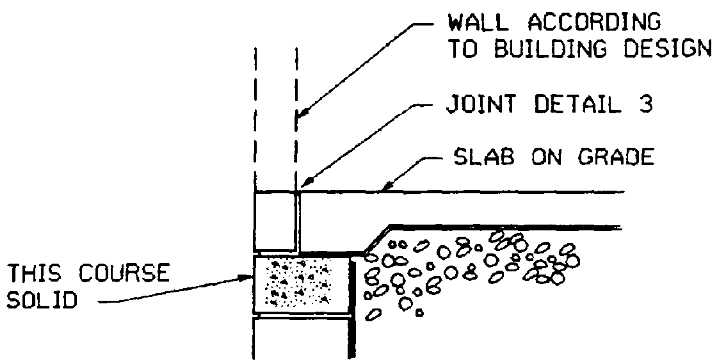
DETAIL 25

INTERIOR WALL WITH
FOUNDATION WALL THROUGH SLAB
CODE A

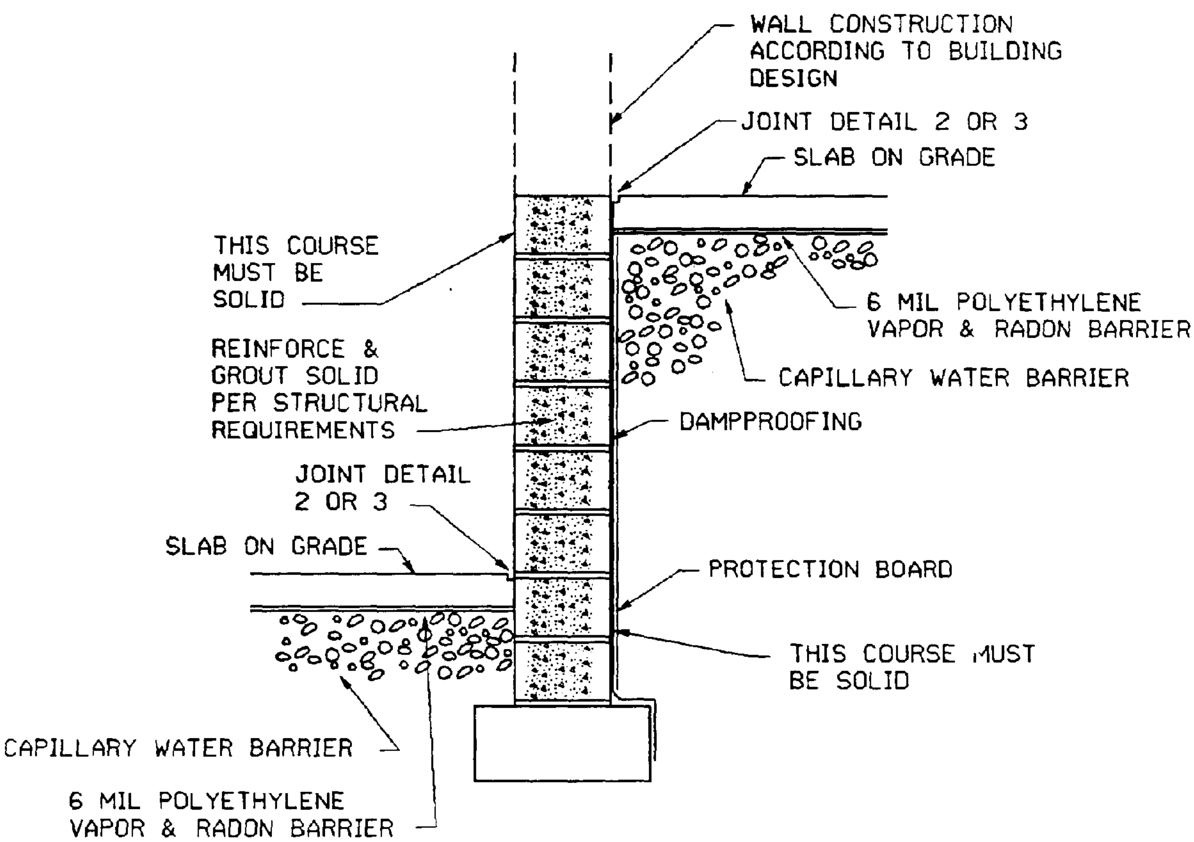


DETAIL 26

INTERIOR WALL WITH SLAB
THROUGH FOUNDATION WALL
CODE A



ALTERNATE DETAIL

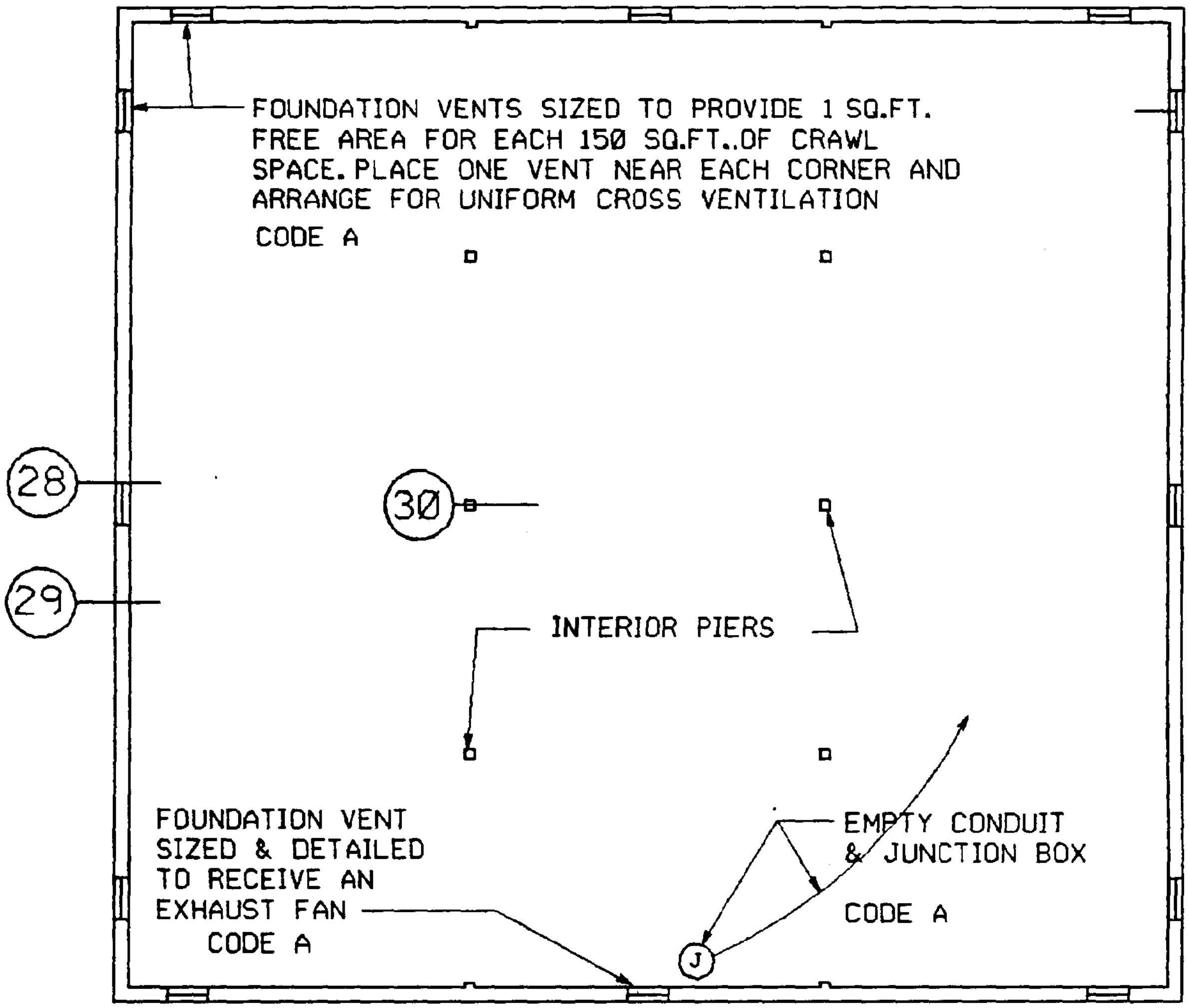


DETAIL 27
INTERIOR WALL WITH CHANGE IN FLOOR LEVEL

CODE A

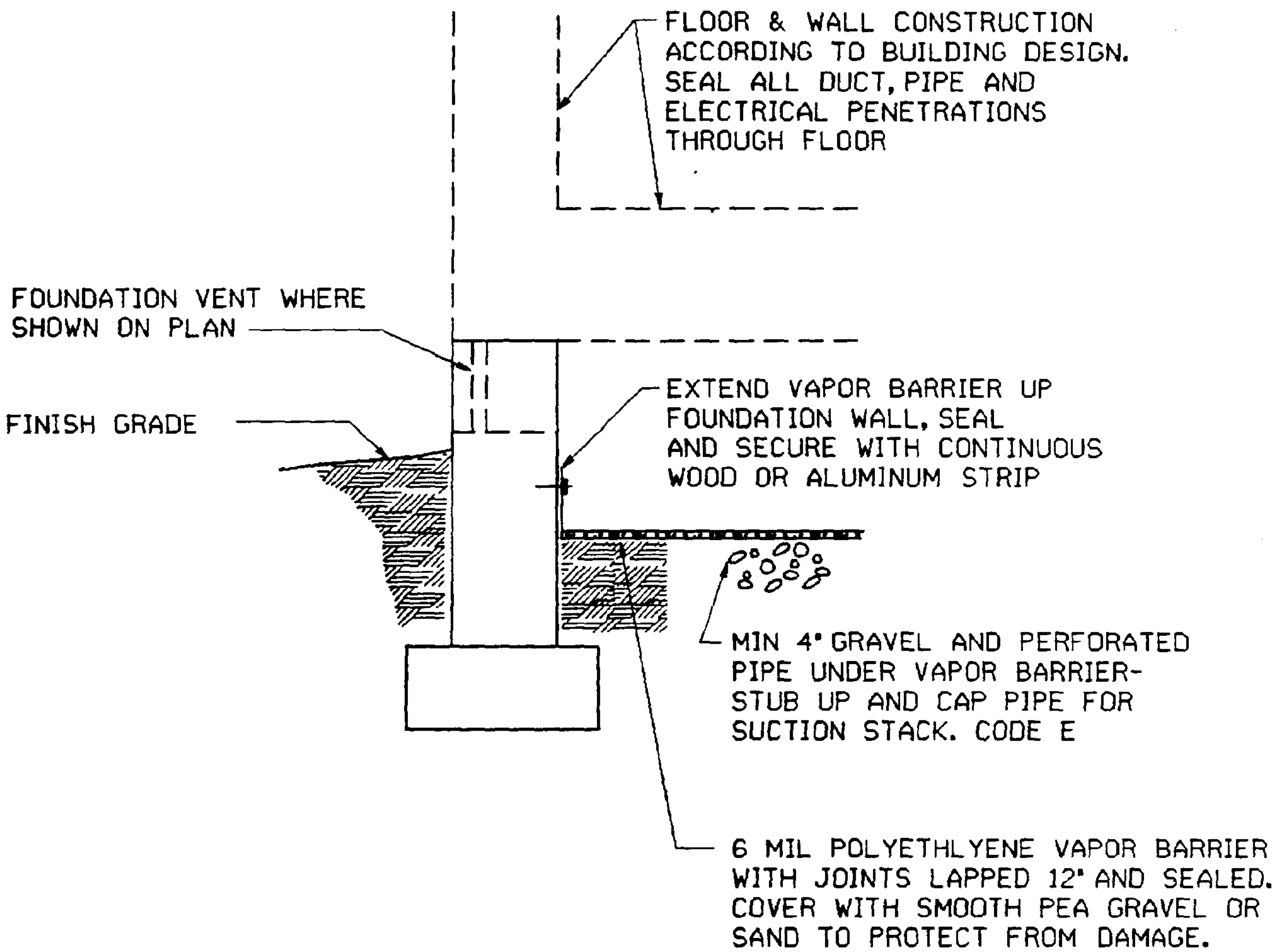
24

MASONRY FOUNDATION



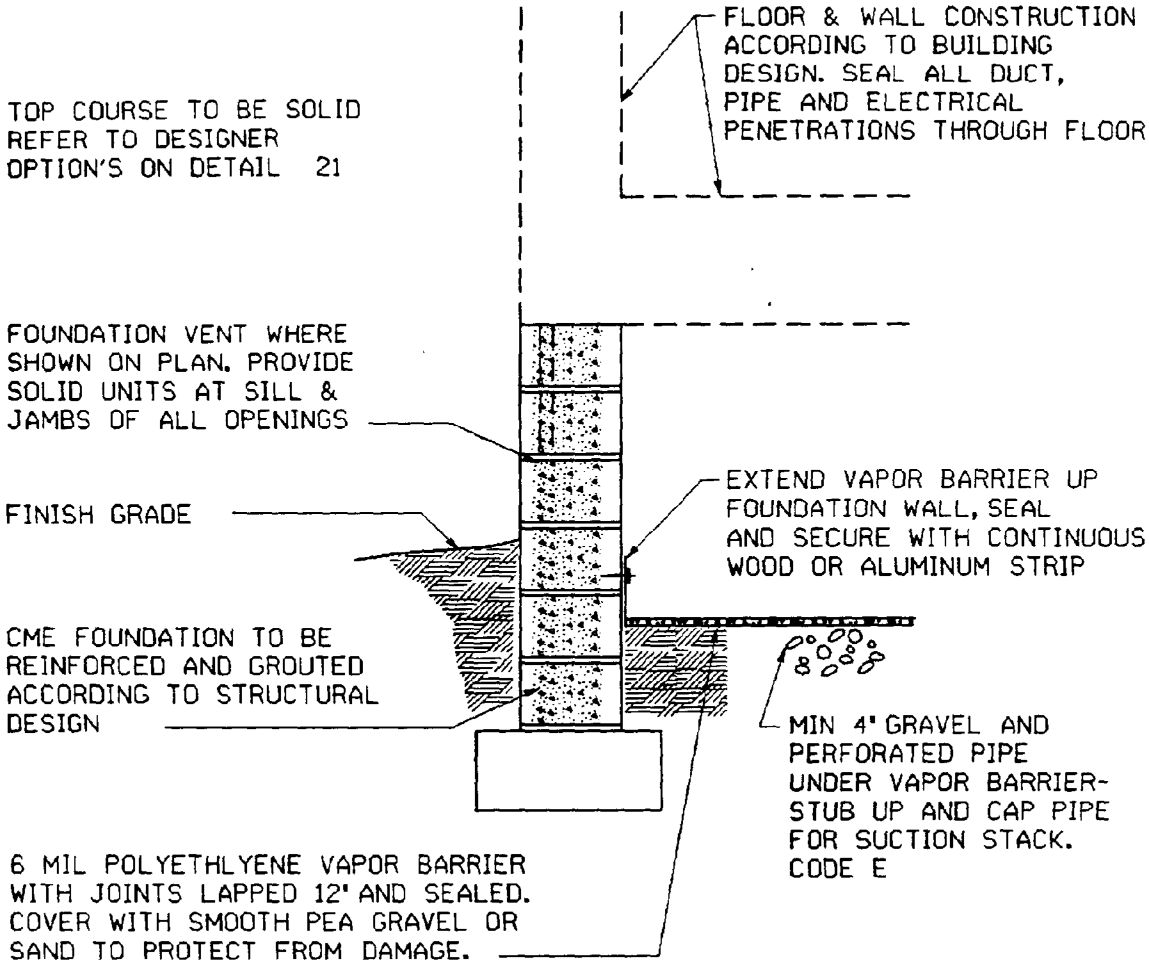
CRAWL SPACE FOUNDATION PLAN

NO SCALE



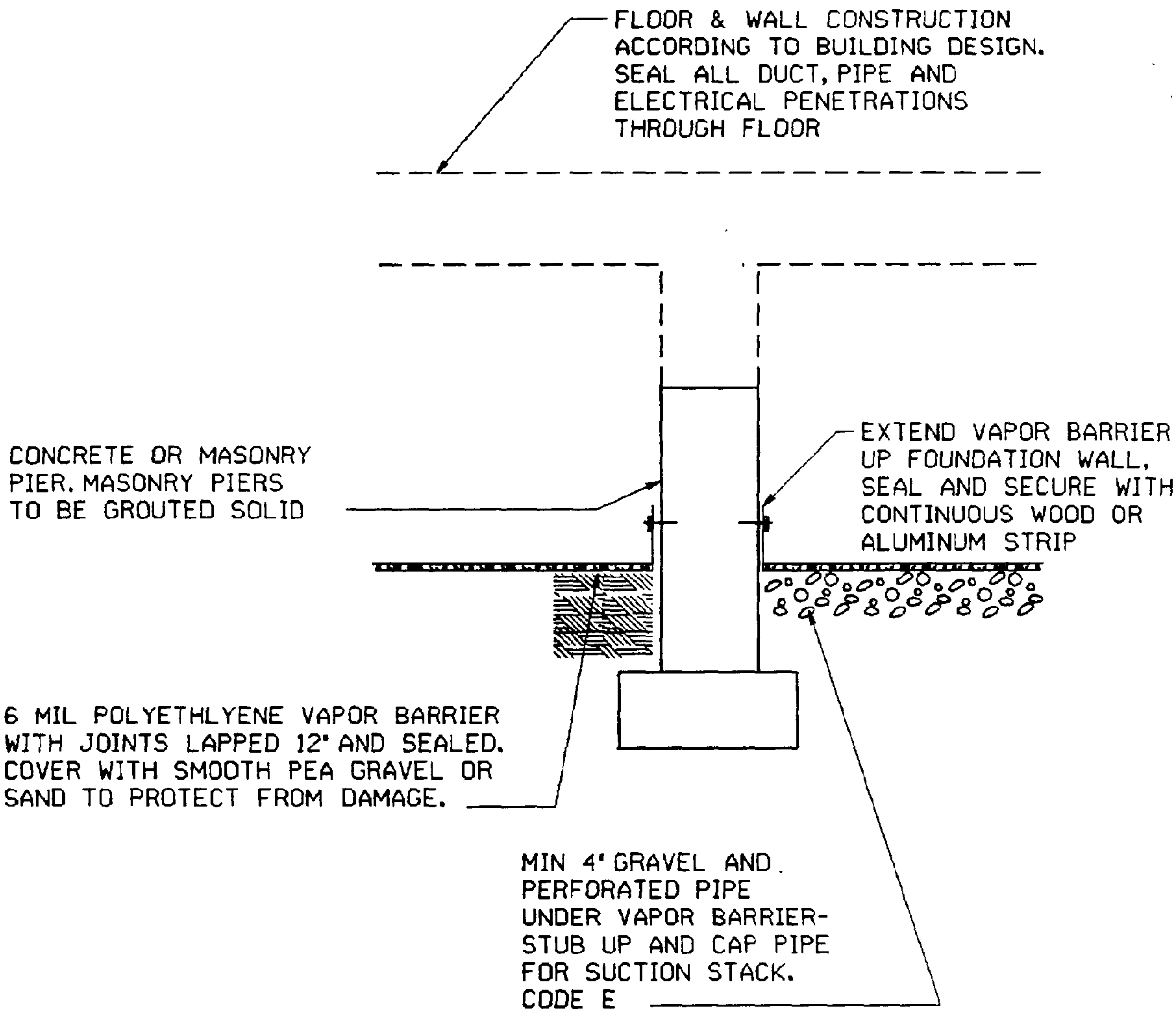
DETAIL 28

EXTERIOR WALL WITH
CONCRETE FOUNDATION
CODE A



DETAIL 29

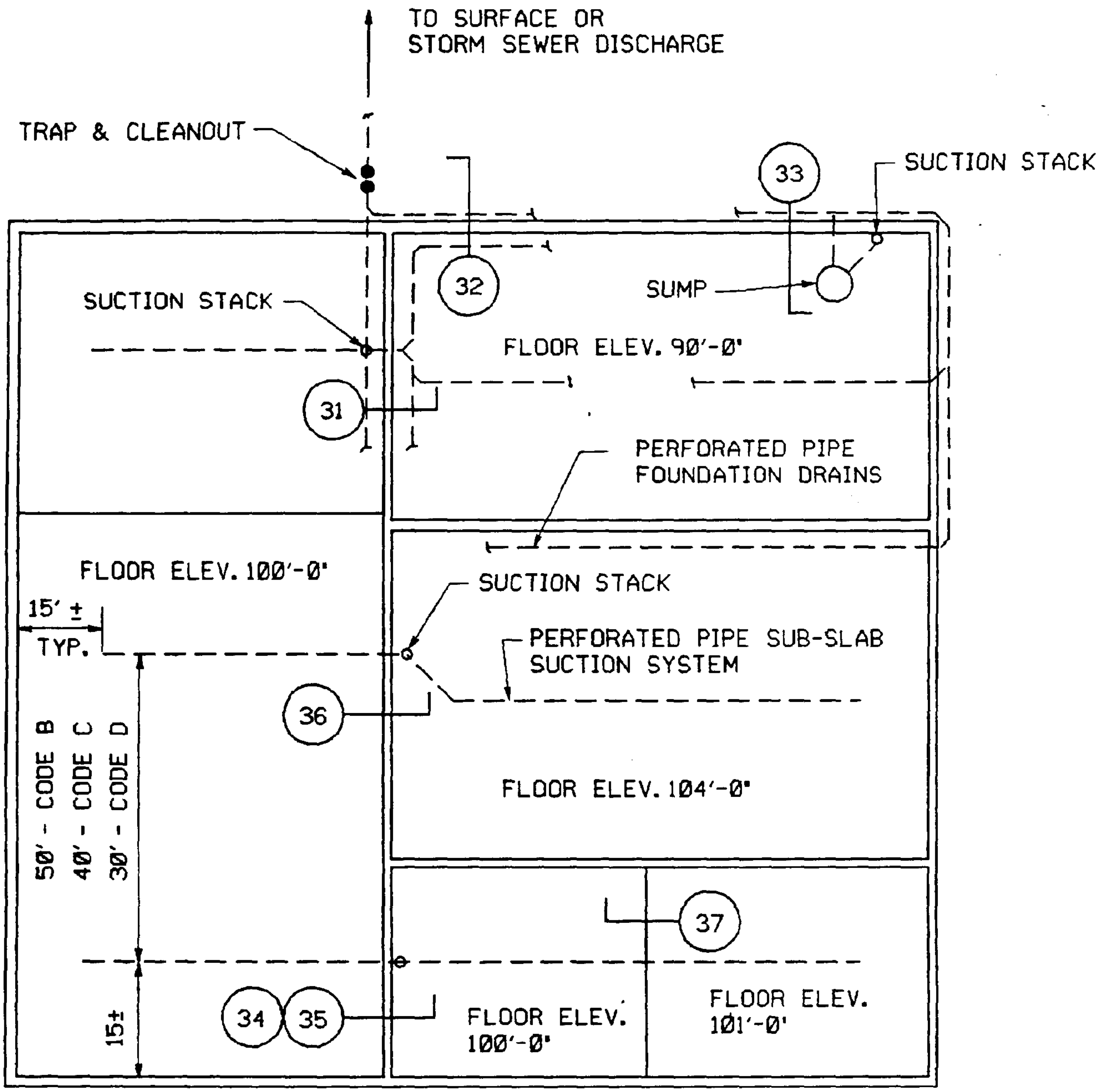
EXTERIOR WALL WITH
MASONRY FOUNDATION
CODE A



DETAIL 30

INTERIOR PIER FOUNDATION

CODE A

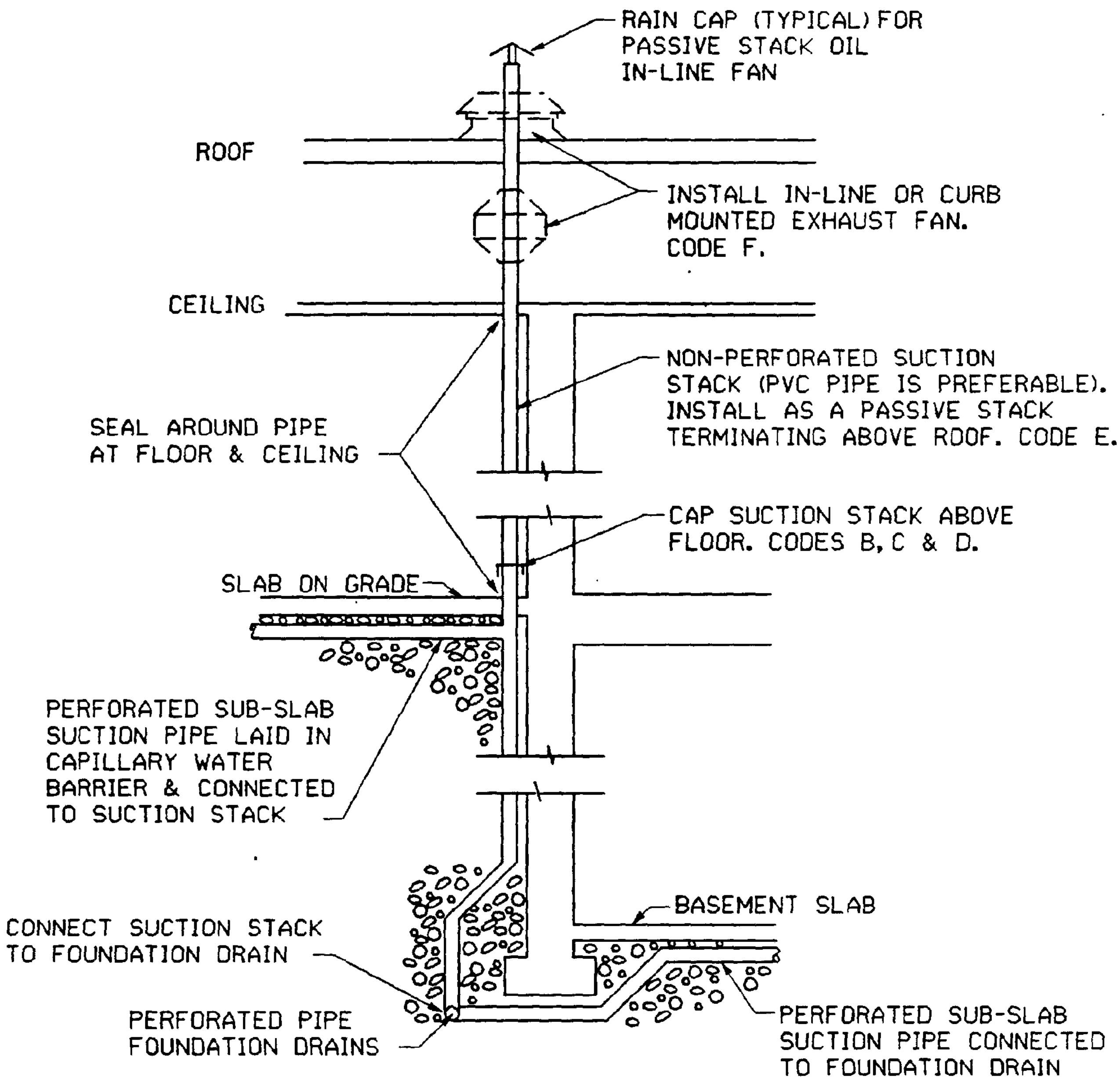


FOUNDATION & SLAB PLAN

NO SCALE

PLAN AND FLOOR ELEVATIONS ARE SHOWN
FOR ILLUSTRATIVE PURPOSES ONLY
CODES AS NOTED

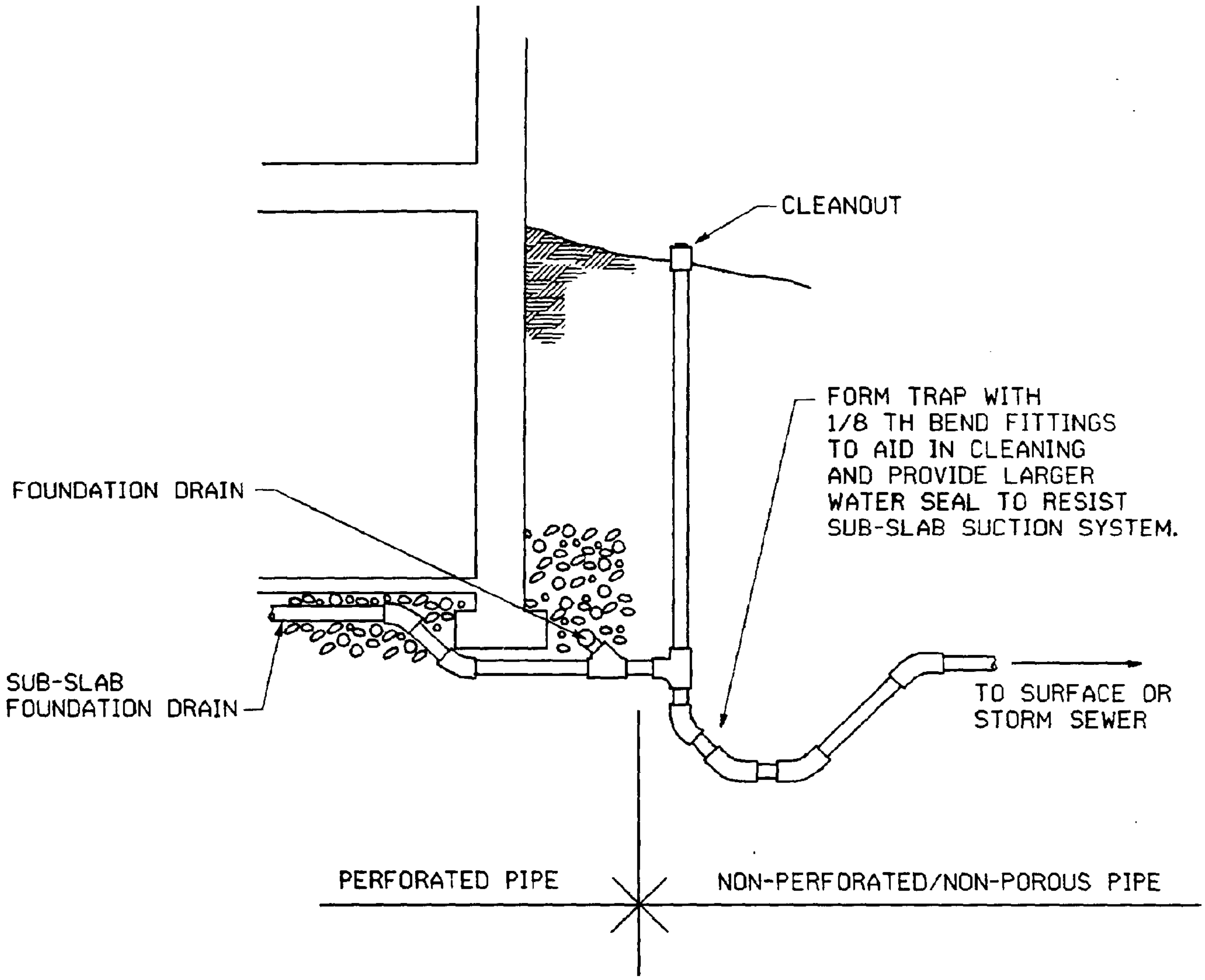
29 SUB-SLAB SUCTION SYSTEM



DETAIL 31

SUB-SLAB SUCTION SYSTEM
USING FOUNDATION DRAINS.
CODES B, C & D EXCEPT AS NOTED

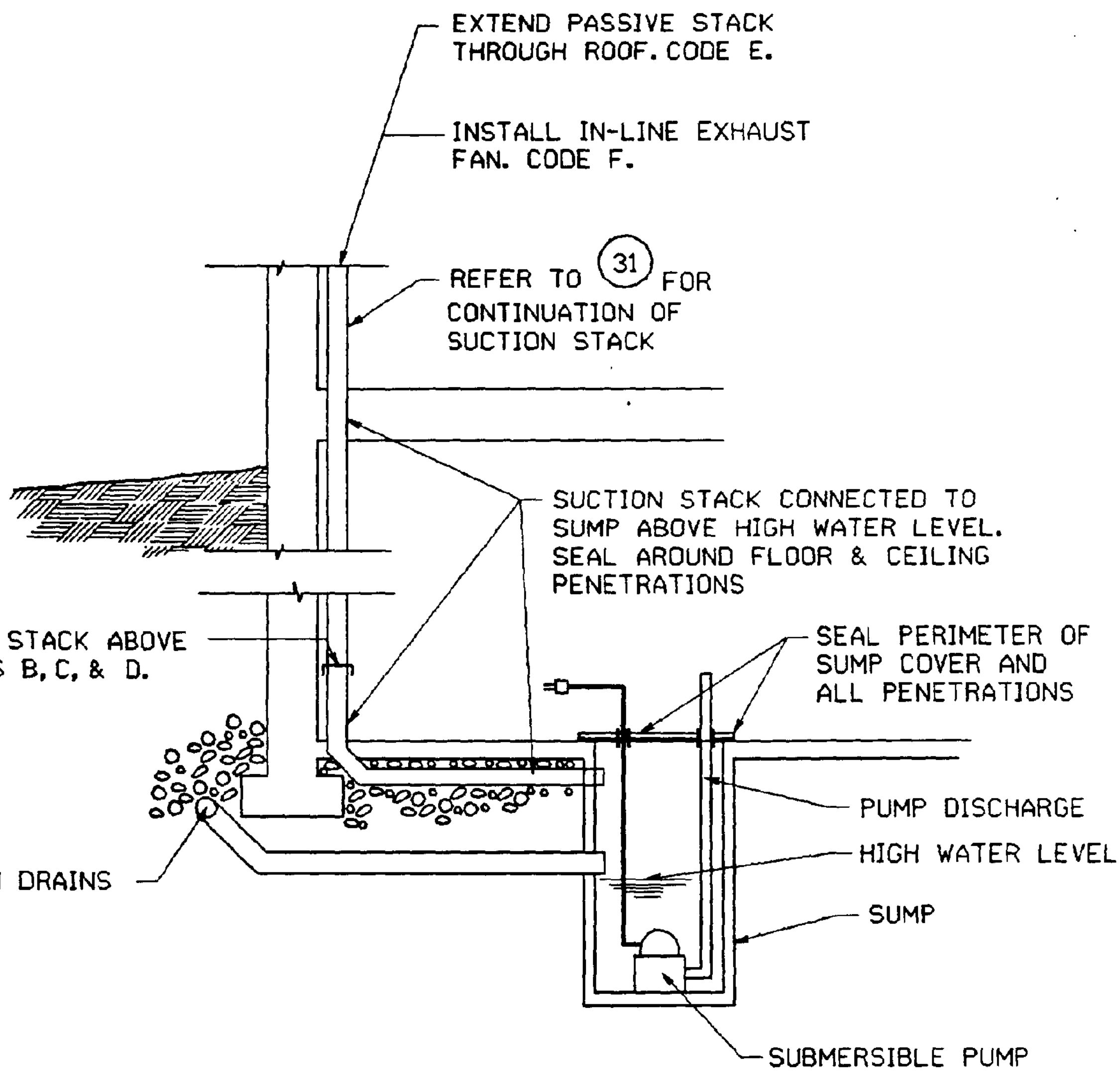
30 SUB-SLAB SUCTION SYSTEM



DETAIL 32

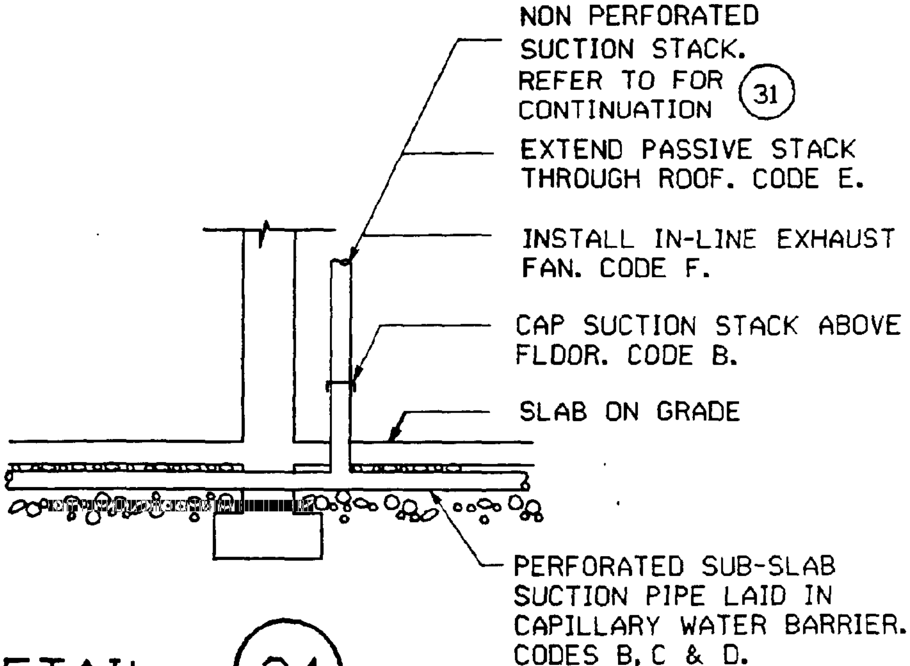
FOUNDATION DRAIN WITH GRAVITY
OUTFALL USED FOR SUB-SLAB SUCTION
CODES B, C, & D

31 SUB-SLAB SUCTION SYSTEM



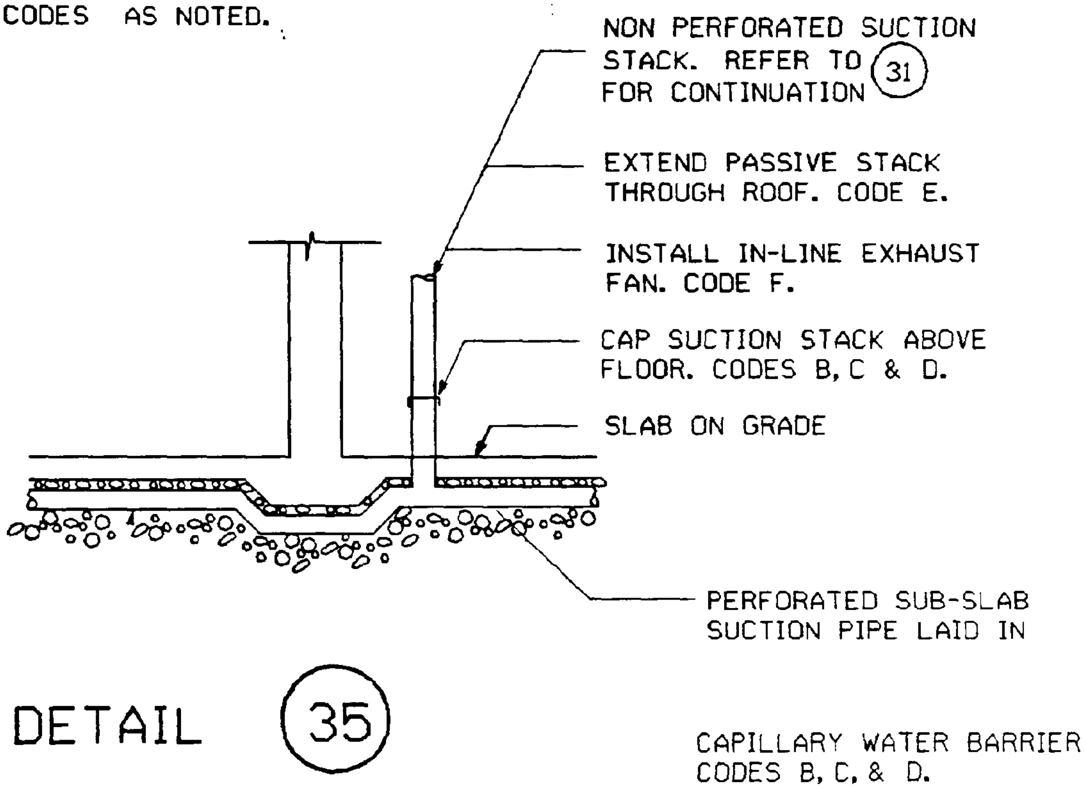
DETAIL 33

FOUNDATION DRAIN WITH DISCHARGE TO SUMP USED FOR SUB-SLAB SUCTION. CODES B, C & D EXCEPT AS NOTED.



DETAIL 34

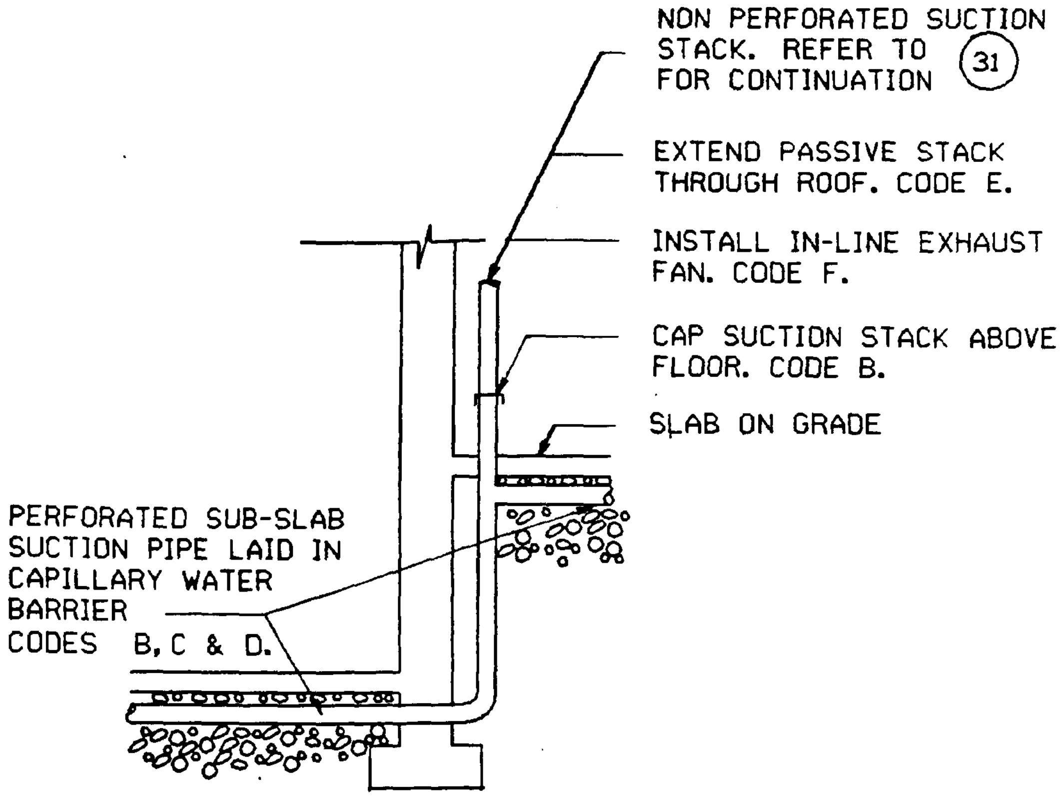
SUB-SLAB SUCTION WITHOUT FOUNDATION DRAINS.
CODES AS NOTED.



DETAIL 35

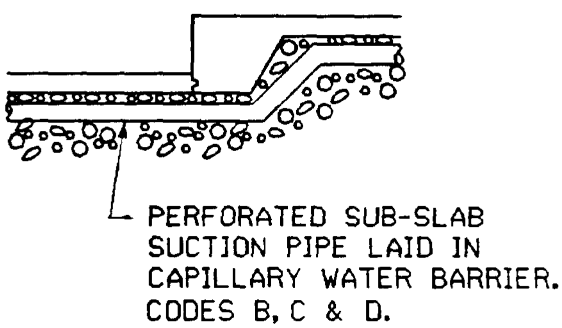
SUB-SLAB SUCTION WITHOUT FOUNDATION DRAINS.
CODES AS NOTED.

SUB-SLAB SUCTION SYSTEM



DETAIL 36

SUB-SLAB SUCTION SYSTEM AT
CHANGE IN FLOOR LEVEL.
CODES AS NOTED.



DETAIL 37